SIMULTANEOUS TELEPHONY AND TELEGRAPHY

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Simultaneous Telephony and Telegraphy

By

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FORMERLY TELEGRAPH AND TELEPHONE ENGINEER
NEW YORK CENTRAL LINES

AND

LOUIS CASPER

GENERAL INSPECTOR TELEGRAPHS

SIMULTANEOUS TELEPHONY AND TELEGRAPHY
Parts 1–2
TELEGRAPH OFFICES

487

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SIMULTANEOUS TELEPHONY AND TELEGRAPHY

(PART 1)

Serial 2103A Edition 1

SIMPLEX AND COMPOSITE SYSTEMS

DEFINITION OF TERMS

1. The transmission of telephone and telegraph messages over the same line circuit at the same time is called *simultaneous telephony and telegraphy.* An arrangement of circuits that will allow the transmission of one telephone and one telegraph message at the same time over one pair of line wires is termed the *simplex system.*

An arrangement of circuits that will allow the transmission of one telephone and two telegraph messages at the same time over one pair of line wires is termed the *composite system.* An arrangement of apparatus that will allow the transmission of one telephone and one telegraph message at the same time over a single line wire, in which arrangement the ground is used as a common return for both the telephone and telegraph currents, is called the *grounded composite,* or *telegraphone system.*

The difference between the simplex and the composite systems lies in the fact that with the simplex system, both conductors of the telephone circuit are used in parallel as one conductor, or, as it is termed, as one Morse wire; while, with the composite, each conductor forms a separate Morse wire. It should be observed that, in the simplex system, the tele-

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graph and telephone currents must not interfere with each other, and in the composite system, in addition to the above condition, the telegraph current on one of the Morse legs must not interfere with that on the other; or, to use a technical expression, there must be no cross-writing.

SIMPLEX TELEPHONY AND TELEGRAPHY

2. There are two methods of forming a simplex; the one is called the *impedance-coil method,* and the other, the *repeating-coil method.* In both these methods, the telegraph current does not interfere with the telephone service, because the telephone apparatus is connected to points in the circuit between which the telegraph current produces no difference of potential. The non-interference of telephone and telegraph currents in simplex systems is not dependent on a difference in the frequencies, but rather on the fact that the telegraph current passes over both sides of the line, which are in parallel, in the same direction, using the ground as a return circuit, whereas the telephone current is confined to the metallic circuit and passes through the two sides in series, the ground not being used as any part of the telephone circuit.

The principle governing the passage of telegraph currents is practically the same in both these systems. The difference between these two systems consists chiefly in the arrangement of the telephone apparatus. In the impedance-coil system, the telephone is connected to the line by means of condensers, and in the repeating-coil method, the inductive characteristic of a repeating coil is utilized for the same purpose.

THEORY OF SIMPLEX OPERATION

3. A skeleton circuit illustrating the current conditions in a simplex system is shown in Fig. 1. It will be noted that the operation of this system is based on the principle of the Wheatstone bridge; that is, when there is no difference of potential between points *a* and *b,* the galvanometer *G* will

remain unaffected. Coils X, X_1, Y, and Y_1 constitute the four bridge arms. The resistance of the arms when the bridge is balanced must be such that the ratio of the resistance values of X to Y is the same as the ratio of X_1 to Y_1.

Consider that the short horizontal lines near a and near b represent line wires of equal resistance; that X equals Y and that X_1 equals Y_1; and that a galvanometer is connected so that a is the same distance from the upper end of X as b is from the lower end of Y. Under these conditions, when current is sent over the bridge, no current will pass through the galvanometer because there is no difference of potential between a and b.

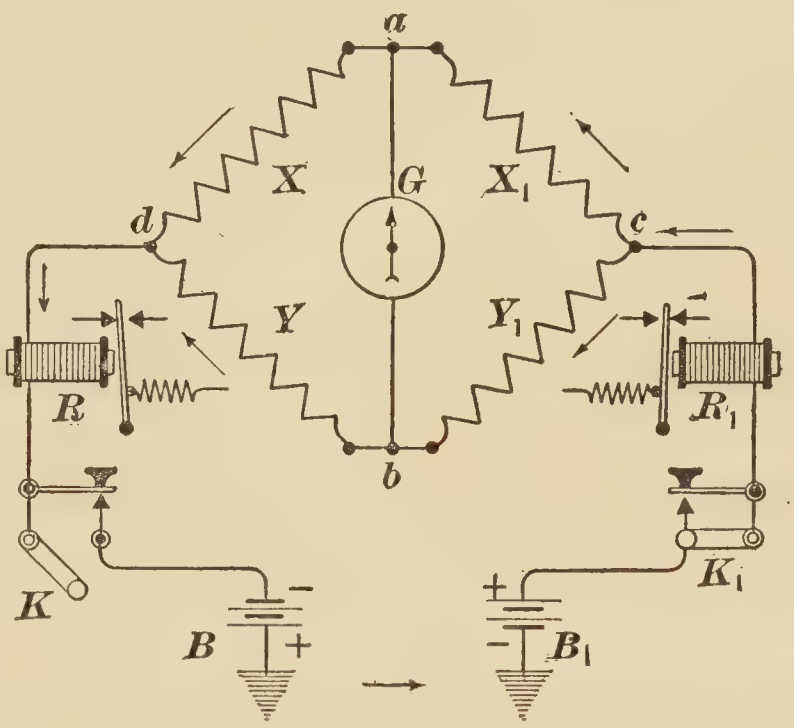

FIG. 1

When keys K and K_1 in series with batteries B and B_1 are closed, current will pass from the grounded battery B_1 through key K_1, and the coils of relay R_1, to point c. Here the current divides, half of it going by way of X_1 and X, and the other half by way of Y_1 and Y. At point d the current is united, and passes through relay R, key K, and battery B to the ground. The arrows indicate the path of the telegraph current. The telephone portion of a simplex system is represented by the galvanometer, which, under the conditions stated, remains unaffected by the passage of telegraph current in the two branches of the circuit.

4. If, in place of a galvanometer, a battery B is connected between points a and b as shown in Fig. 2, the current from this battery will be confined to the metallic circuit as indicated by the arrows; no current will pass through the telegraph circuit. This may be proved as follows: As the arms X and Y

are equal, point d will be equidistant in potential from points a and b; likewise X_1 and Y_1 being equal, point c will be equidistant in potential from a and b. Therefore, points c and d are equidistant in potential from points a and b; hence, there will be no difference of potential between these points to force current through the telegraph circuit consisting of the relay R, the earth, and the relay R_1. This illustrates that the telephone system, represented in this case by the battery B, sends no current through the telegraph branch of a simplex circuit.

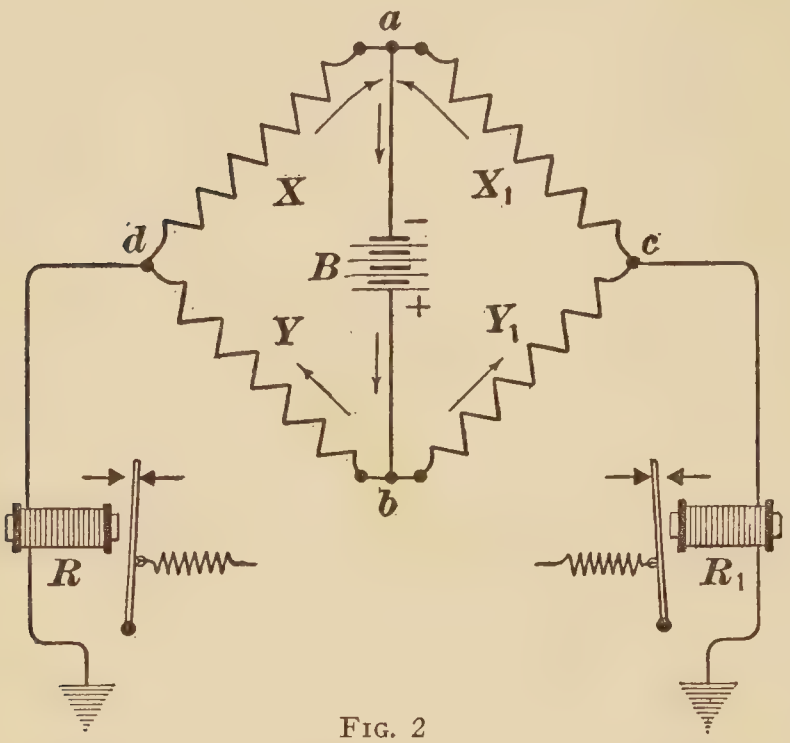

FIG. 2

IMPEDANCE-COIL METHOD

5. Fundamental Circuit.—M. Cailho, a Frenchman, was about the first to devise a simplex system using impedance coils. The essential feature of his arrangement, which is shown in Fig. 3, consists of an *impedance, retardation,* or *choke, coil,* as it is variously termed, composed of two identical windings D and E of insulated copper wire, each having exactly the same resistance and the same number of turns wound on the same soft-iron core. The object of the impedance coils D and E is to prevent the telephone current from passing through the coils, it being assumed that the telephone or generator of Fig. 3 is in theory the same as the battery B of Fig. 2. Relay R, Fig. 3, is a telegraph relay of about 500-ohm resistance. The telegraph key K is provided with a switch to short-circuit the key when it is not being used for sending a telegraph message. The main-line battery $M\,B$ is used for operating the telegraph relays. The telegraph relay R, by the

action of its armature, controls a local circuit containing a telegraph sounder and a local battery.

To prevent voice currents from passing through the generator circuit, a manual or automatic device is provided, as shown at *N*, that normally keeps the generator circuit open. When the generator handle is turned, the circuit must be closed at *N*, either automatically or by hand. The telephone transmitter and battery are shown at *T* and B_1, respectively. The primary and secondary windings of a telephone induction coil

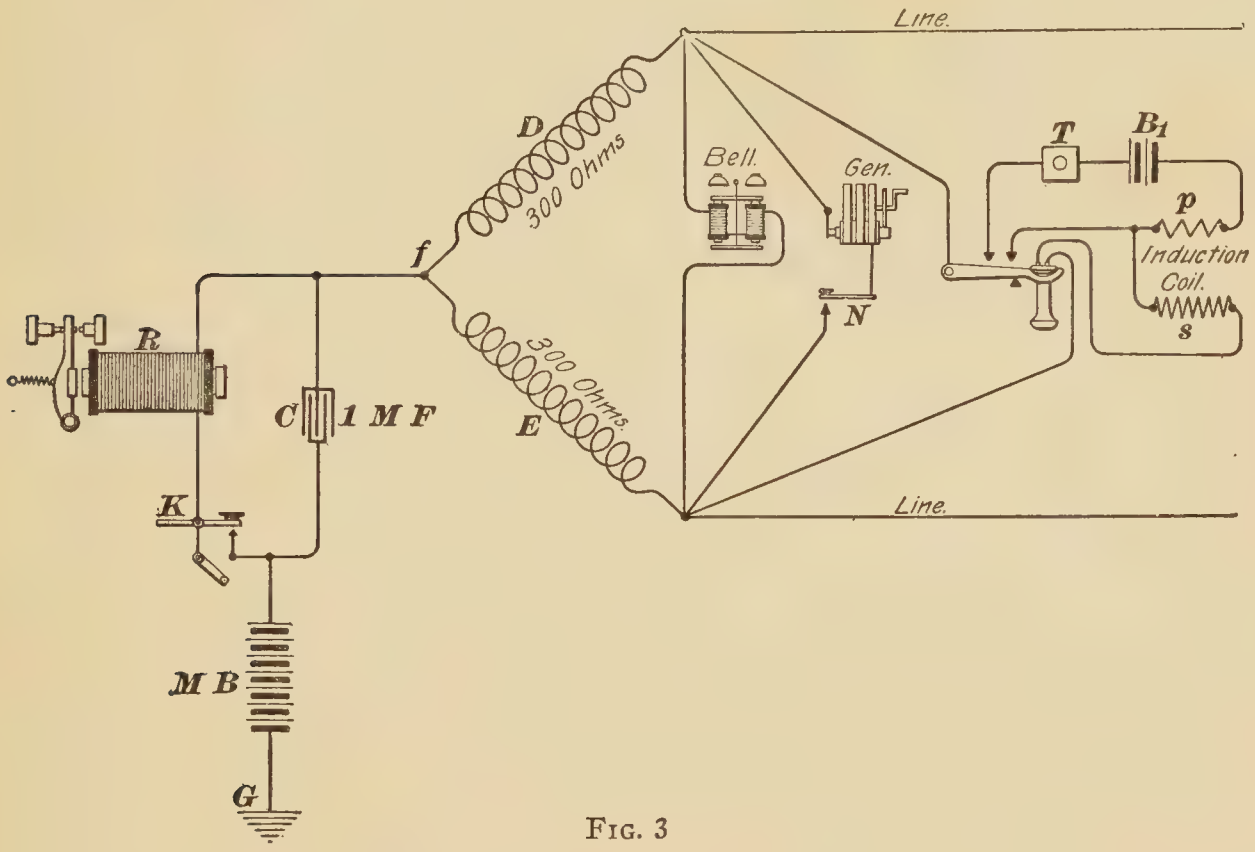

FIG. 3

are shown at *P* and *S*, respectively. This is an ordinary local-battery telephone with magneto signaling.

6. The telegraph currents divide at point *f*, Fig. 3, into two equal parts, since the two paths have equal resistance, and pass through the two windings in opposite directions around the iron core, so that the two coils tend to magnetize the iron core equally, but in opposite directions; consequently, the self-induction will be practically zero and the impedance to the telegraph current will be no greater than the resistance. For the telephone currents, however, the two halves *D* and *E* are in series, and since the frequency of the voice currents is very much greater than that of the telegraph current, the impedance

offered by the coil to the voice currents will be very large, thus forcing practically all the current coming from the distant station through the telephone where it belongs. Thus the coils prevent the telephone currents from passing through them, but as they add only one-half of the resistance of one coil to the telegraph circuit (since there are two coils in parallel), they do not interfere appreciably with the telegraph signals, if proper coils are used.

If care is taken that the two halves *D* and *E* of the coil have exactly the same resistance and number of turns, and that the two line wires are reasonably equal in resistance, clicks in the telephone will not seriously interfere with talking, although they may sometimes be heard. It has been demonstrated that a perfect balance may be obtained with ordinary commercial coils, with the result that all sound of Morse clicks is eliminated. However, if the clicking persists it may be almost, if not entirely, obliterated by connecting a condenser *C* of 1- or 2-microfarad capacity around the telegraph relay and key at each station. With this arrangement there is considerable drag in the telegraph signals caused by the action of the condenser in affecting the current impulses of the telegraph circuit, and where the clicking in the telephone receivers is not objectionable the condenser should be avoided.

7. Dimensions of Impedance Coils.—One type of impedance coil has an iron core $\frac{5}{16}$ inch in diameter, a length between heads of $3\frac{1}{16}$ inches, and is wound to a depth of about $\frac{1}{8}$ inch with No. 36 insulated B. & S. copper wire, giving a resistance of 600 ohms. If wound with No. 31 B. & S. wire, this same coil will have a resistance of about 50 ohms. The whole is iron clad, that is, closed by an iron cylindrical shell $\frac{1}{16}$ inch thick and by two iron end plates. The iron parts are firmly fastened together by a screw at each end. The induction coil is the one generally used by the Bell Companies in their bridging telephones having 1,000-ohm bells and solid-back transmitters. The secondary winding of the induction coil has a resistance of 14 ohms, and the primary winding a resistance of $\frac{1}{2}$ ohm.

M. Cailho successfully used coils of lower resistance at *D* and *E*, Fig. 3, but the inductance was made high. For long line circuits *D* and *E* should each be choke coils of at least 600-ohm resistance. Morse relay magnets, having a resistance of 500 or 600 ohms, or 1,000-ohm telephone-bell magnets, as will be shown in Pfund's system, may be used in place of special impedance coils. Where Morse relay or bell magnets are used, the point *f* will be the junction of the two coils. The talking qualities of the telephone are not interfered with and ordinary bridging telephones may be used.

8. Intermediate Telegraph Station.—The arrangement of an intermediate telegraph station is shown in Fig. 4. Condensers *C*, not exceeding 2 microfarads, are connected in the line wire and 600-ohm retardation coils *I* are connected across the two line wires. The telegraph apparatus is connected to the middle points of the two pairs of retardation coils. Condensers *C* must be accurately balanced to prevent noise on the line. Unbalanced condensers will make the line noisy, as if it had a high-resistance joint in one side of it. The intermediate telephone, shown in the same figure, is bridged across the line wires; this telephone is generally in series with a condenser.

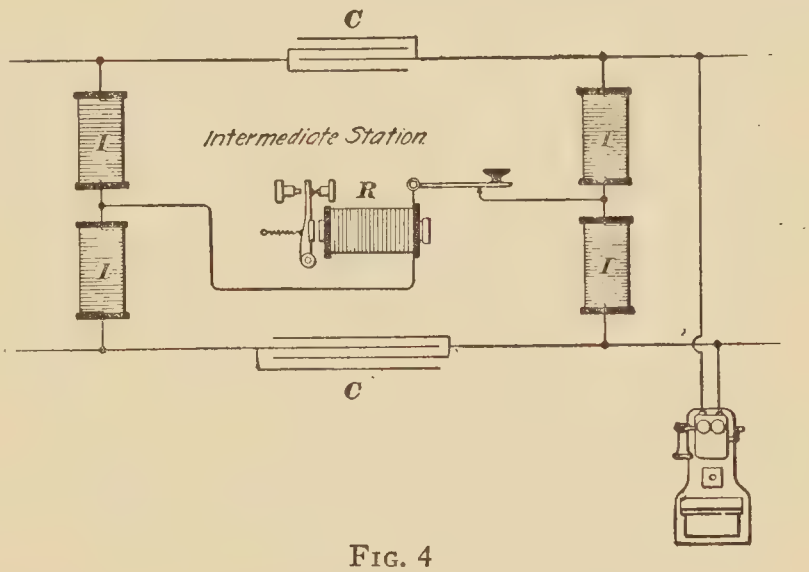

FIG. 4

BELL SIMPLEX SYSTEM

9. Circuit Connections.—The Bell long-distance companies formerly used the system shown in Fig. 5. It will be seen to resemble closely M. Cailho's method. The telegraph circuit is connected to the center *a* of a retardation coil *b c*, which has a total resistance of 1,000 ohms and is bridged

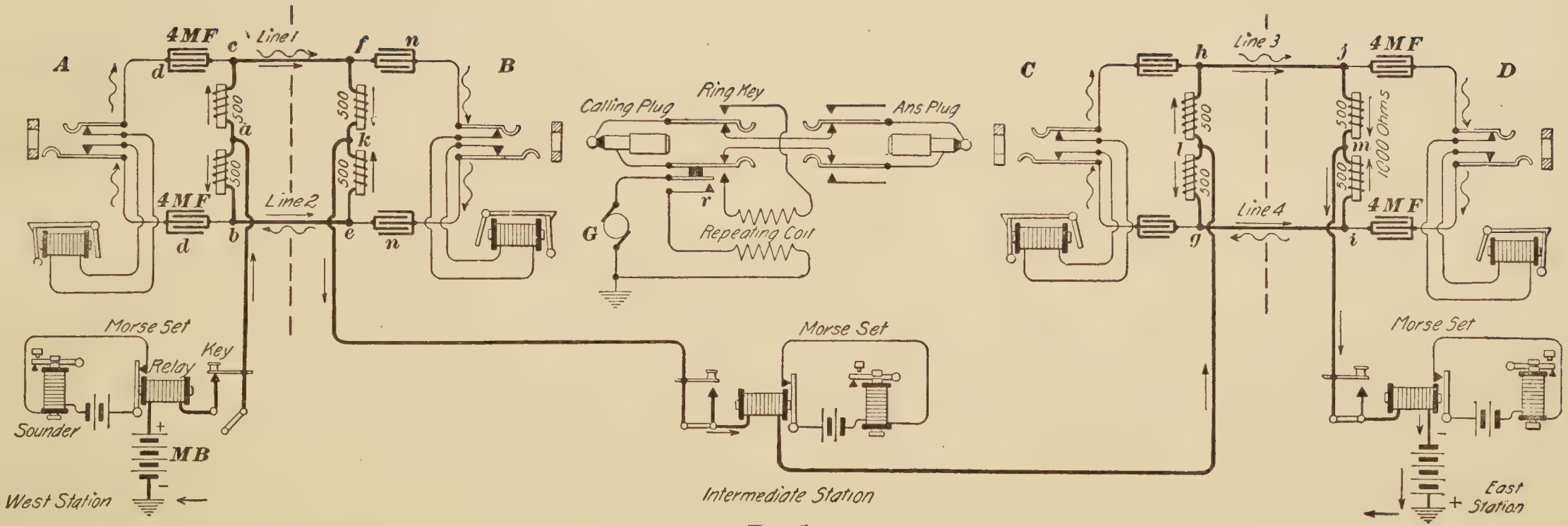
A
4MF
d
c
Line 1
f
n
B
500
a
500
k
4MF
d
b
Line 2
e
n
Calling Plug
Ring Key
Ans Plug
r
G
Repeating Coil
C
h
Line 3
j
4MF
D
500
l
500
500
m
1000 Ohms
4MF
g
Line 4
i
Morse Set
Relay
Key
Sounder
MB
West Station
Morse Set
Intermediate Station
Morse Set
East Station

FIG. 5

across the line. From the coil *b c* wires run to two condensers *d* of 4-microfarad capacity each, and from there to a jack and drop located at the toll switchboard. From the coil *b c* the wires also run to a test board, to the main distributing frame, and to the toll line wires *1* and *2*. Similar retardation coils *e f*, *g h*, and *i j* are connected across the line wires at each exchange. The middle points of the four coils are at *a*, *k*, *l*, and *m*. In fact, the entire arrangement at each exchange *A*, *B*, *C*, *D* is similar.

10. The principle of operation is as follows: Current from the main-line Morse battery *M B*, Fig. 5, passes through the two halves of the 1,000-ohm coil *b c* in parallel, the joint resistance of which is one-half of 500, or 250 ohms. The two 4-microfarad condensers *d* offer high impedance to the passage through them of the relatively low-frequency telegraph current. Thus very little telegraph current enters the telephone circuit. The telegraph current passes out over the line as indicated by the straight arrows. At the receiving office *B*, the same conditions prevail; the current, passing through the retardation coil *e f* reaches the Morse set in preference to passing through the condensers *n*, which would disturb the telephone circuit.

The telephone current readily passes through the condensers, but not through the retardation coils, which are bridged across the line wires, because the impedance of one retardation coil *b c* to the high-frequency telephone current is equivalent to a total resistance of about 30,000 ohms; hence, it follows that little or none of the telephone current will be shunted through any impedance coil. At the receiving office *B*, the conditions are the same, since the telephone current passes through the condensers *n* in preference to passing through the retardation coil *e f*. The straight arrows indicate the path taken by the telegraph current, while the wavy arrows indicate the path of the telephone current.

The impedance coil used consists of four windings, or separate coils, on the same iron core. The four windings are connected in series across the line wires, so that any current passing from

one line wire through the coil to the other line wire, must pass through the four windings. The windings are so arranged that they assist each other in magnetizing the iron core in the same direction, thus giving the whole coil a maximum impedance for the telephone currents.

11. Intermediate Stations.—With the Bell simplex system a number of Morse sets can be worked together on the same line. In Fig. 5, three Morse instruments are shown connected in series in a circuit that is subdivided so as to allow the use of two independent telephone sets at the same time. Thus a through telegraph circuit may be obtained from the exchange *A* through the two exchanges *B* and *C* to a fourth exchange *D*. Stations *B* and *C* may be the same exchange or they may be exchanges in different places with the intermediate telegraph station located anywhere along the single line wire extending from point *k* to *l*. If no intermediate telegraph station is required and exchanges *B* and *C* are some distance apart, the points *k* and *l* may simply be connected together by a line wire.

If an intermediate telegraph station is required on a through pair of telephone wires, then the Morse set is connected at the intermediate station, as shown, and the end *f* of the coil *e f* is connected through a condenser to end *h*, and the end *e* of the coil *e f* is connected through another condenser to end *g*. Balanced condensers are used, and the jacks, drops, and other condensers at stations *B* and *C* are omitted. The connections would then be the same as shown in Fig. 4.

All the cells required to operate telegraph relays, Fig. 5, may be located at any station. A better arrangement, however, is to divide the cells equally between adjacent telegraph stations, that is, about half the cells may be located at each terminal station. This arrangement is usually the most convenient as well as the most satisfactory. All cells or batteries used in the same telegraph-line circuits must be connected in series. The condensers *n* at the intermediate telephone station serve the same purpose as the condensers *d* at the terminal station.

12. Western Electric Impedance Coil.—The 1,000-ohm impedance, or retardation, coil, as constructed by the Western

Electric Company, and used by the Bell Company in its impedance-coil simplex systems, is shown in Fig. 6 (*a*). On each spool there are two windings, one over the other; the inside winding on one spool is connected to the outside winding on the other spool, as indicated in Fig. 6 (*b*), so that the maximum amount of magnetism is produced in the iron core when the coils are in series. The two coils on the left spool must each tend to produce a north pole at *N* and a south pole at *S*, and the two coils on the right spool, a north pole at *N'* and a south pole at *S'*, as indicated in the figure. The telegraph circuit is connected to coil *m n*, view (*a*), at its center point *e*. The

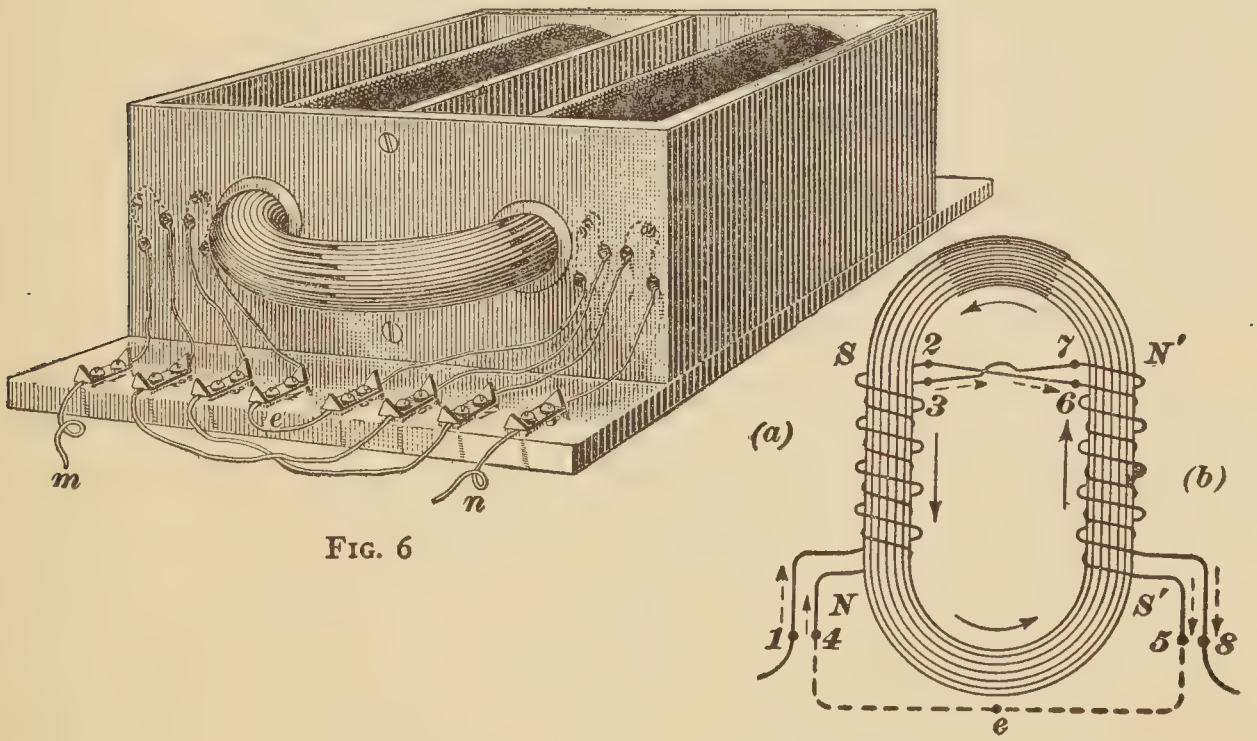

FIG. 6

core is made of a bundle of annealed Norway iron wires of about 25 B. & S. gauge, the ends of the bundle being interlaced and held in place by a wrapping of iron wire. The terminals of the windings are brought out to clips, numbered in the manner shown for convenience in connecting. The dotted coils, near the points where the wires enter the case, merely indicate the windings on the spools. The coil is mounted on a wooden base and protected with a case made of $\frac{1}{2}$-inch wood. The figures *1, 2, 3,* etc., view (*b*), correspond with the terminals of view (*a*).

13. Simplex Coil.—An impedance coil used by independent companies and suitable for use on a simplex circuit is

shown in Fig. 7. It has four windings *a, b, c, d,* each containing 2,400 turns of No. 29 B. & S. silk-covered copper wire. One half is formed by connecting together windings *a* and *d*; the other half by connecting together windings *b* and *c*. Each half will have a resistance of 120 ohms. The iron wires forming the core are 13½ inches long, and are bent back so as to overlap around the outside of the coils. Mutual induction is prevented by enclosing each coil in a shell of iron, as shown. On account of its great impedance and in spite of its low resistance, this coil may be used across a line having 1,600-ohm bells. The coil may be wound with 4,800 turns of two No. 29 wires side by side; this will give a better balanced coil, but it

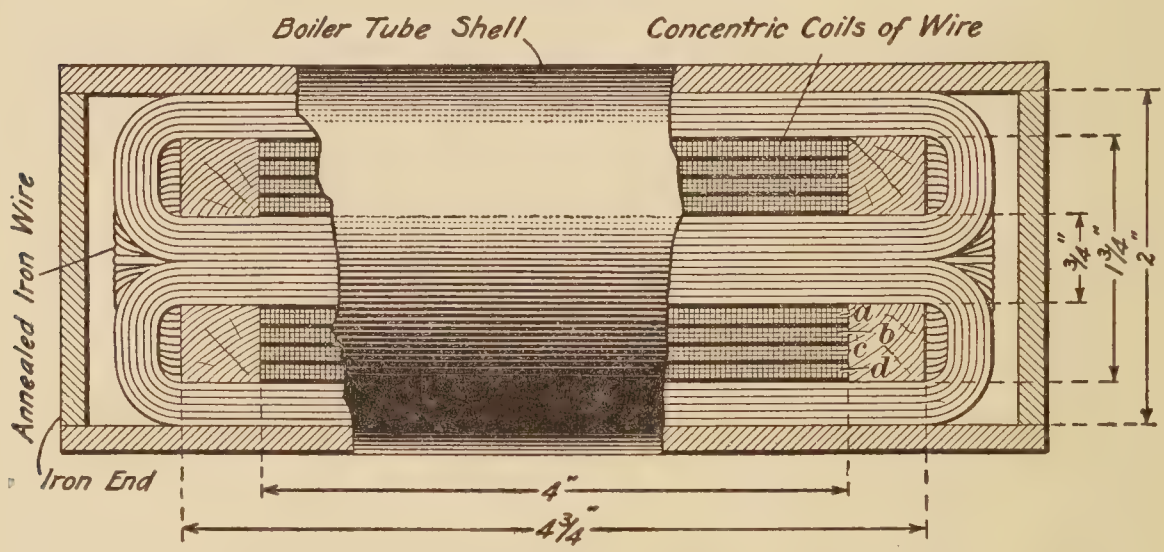

FIG. 7

is rather difficult to wind and is more liable to break down, as the potential between two parallel wires is greater in this arrangement.

14. It is quite permissible to ring on an impedance-coil simplex circuit with an ordinary generator provided the generator is not grounded; the impedance of the coil is so great that very little of the ringing current can pass through it. If a grounded generator is used, however, it will affect the Morse circuit to some extent, especially if the relays are adjusted to work with a small change in the strength of the current or, as telegraph operators say, to work with a small margin.

In case it is necessary to use a grounded generator to ring on a simplex circuit, the current from the generator *G*, Fig. 5, may be passed through one winding of a suitable repeating coil,

the other winding of which, being free from a ground, may be connected to the regular ringing key. This key, should, however, be provided with an extra pair of contacts *r*, which close the generator circuit when the ringing key is operated. All interference with the telegraph relays will be avoided by this arrangement.

Since the Morse current affects both line wires and both condensers *d* at the same time and equally, there is no effect whatever from it in the telephone receiver; the telephone is made more quiet because of the bridging of the impedance coils across the circuit.

15. Advantages and Disadvantages of Impedance-Coil Simplex.—The impedance-coil simplex system is much cheaper to install than the composite. It also possesses the advantage of enabling the telephone operator to signal in the usual manner with an ungrounded generator without affecting the telegraph instruments. Furthermore, a number of telegraph stations may be connected in the same line circuit.

The principal disadvantages of the impedance-coil simplex system are as follows: It gives but one telegraph circuit over a pair of wires, whereas the composite gives two telegraph circuits over the same pair of wires; interference with the telegraph service results when signaling with generators that are accidentally or permanently grounded. This trouble may be remedied by the use of an ungrounded generator, but the same circuit is often connected to other long-distance lines extending to many offices, any one of which, by ringing with a grounded generator, interferes with the telegraph service.

Another objection is that unless condensers are used between the impendance coil and the terminal of the line on the toll board, the Morse circuit is liable to become grounded by the connection of this circuit by the toll operator to another long-distance line that is accidentally grounded. The last two objections may be eliminated by terminating the simplex lines in smaller jacks on the toll board, and using connecting cords that contain repeating coils and terminate in one large and one small plug. This slightly interferes with the rapid handling

of the telephone traffic, and the repeating coil cuts down the talking efficiency somewhat.

16. For the best service with the simplex circuit using impedance coils, the total resistance of the Morse sets should be high; that is, each telegraph relay should have a resistance ranging from 150 to 500 ohms. It is not necessary that the resistance of the impedance coils should be so very high, but only their inductance. As already shown, a ringer may be used as an impedance coil, its terminals being bridged across the telephone line, and a telegraph circuit attached to the junction of the wires between the two spools. If the coils are at all equal, this arrangement will be successful. If a number of circuits are so equipped, the ringers must not be placed too close together with cores parallel, or cross-talk between the circuits will result. Cross-talk, which is caused by mutual induction between adjacent coils, may be prevented by placing the adjacent ringers with their coils at right angles to each other. A high-impedance tubular drop with an accessible middle terminal may also be used for the impedance coil and no cross-talk will result. If high-resistance ringers and drops are used, the telegraph relays may have a high resistance, 300 to 500 ohms.

17. Signaling on Simplex Circuit.—In case it is not advisable to use an ordinary hand generator, signaling over a simplex circuit may be accomplished by the arrangement shown in Fig. 8, in which *x y* is the impedance coil used in simplex systems, *R* an ordinary receiver connected to the jack *J* in the same manner as an ordinary drop, *T* a transmitter in front of which is permanently fixed a receiver *H* and *V* an ordinary battery bell with the vibrating contact disconnected, so the bell will give a single tap on the transmitter case when the circuit through its coils is closed at *n*. The receiver *H*, transmitter *T*, bell *V*, and induction coil *s p* may be permanently mounted in an empty bell box having binding posts *a*, *b*, *c*, *d*, *e*, *f*. The battery *B* consists of four or five primary cells. At *P* is shown an ordinary calling plug and at *K* a ringing key provided with an extra pair of contacts *n*. When key *K* is

closed contacts *n* will also be closed, thereby closing a circuit through *B-a-T-V-p-d-n-c-b,* which will cause bell *V* to tap the transmitter once, thus starting the transmitter to vibrating. If the receiver circuit is also closed, the receiver will also vibrate and the transmitter and receiver will continue to vibrate until the receiver circuit is opened at the distant station, or the battery circuit is opened at contact *n*. If plug *P* is inserted in the jack of a line and key *K* is closed, the distant receiver, which is connected to the line in the same manner as receiver *R*, will give forth a sufficiently loud howling sound to attract the operator's attention. This arrangement has the

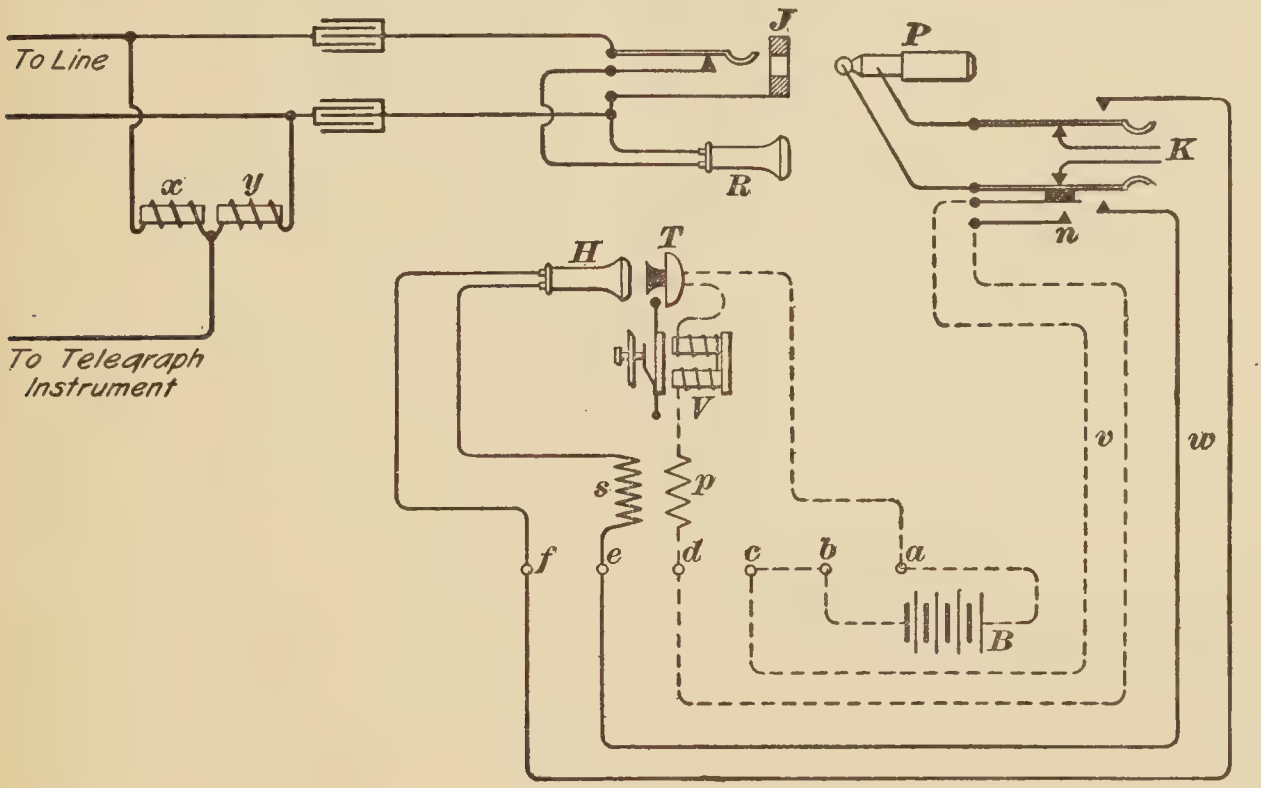

FIG. 8

disadvantage of giving the operator only an audible signal, and it could be used only where there is but one or two such simplex circuits.

The distance between the receiver *H* and the transmitter *T*, and the number of cells used for the battery *B* may be adjusted, when the apparatus is originally set up, until the desired sound is produced. If desired, this set may be connected to a plug used solely for signaling on such circuits; in which case the wires *w* will run directly to the signaling plug, the wires *v* will run to a simple push button, and the signaling plug, after signaling on a line, will be withdrawn from the jack and a regular

calling plug inserted in its place. This arrangement of circuits may also be used as a howler to call a subscriber who has left his receiver off the hook.

A standard composite ringer, as explained later, is to be preferred to this method of signaling on lines on which it is difficult to obtain satisfactory ringing with ordinary generator ringing current.

REPEATING-COIL METHOD

18. Circuit Connections.—A simplex system, secured by the use of repeating coils, is shown in Fig. 9, in which *a b* represents a repeating coil at station *A*; *c d* a repeating coil at an intermediate station *B*; and *e f* a repeating coil at station *C*. A repeating coil is inserted permanently in the circuit wherever a telegraph tap is desired. At the intermediate telegraph station, the telegraph apparatus is connected to the middle points *g* and *h* of the two windings of the repeating coil. Coils may be obtained with a connection made to the center of one or both windings for this purpose.

When all the telegraph keys K, K_1, K_2 are closed, all the telegraph relays R, R_1, R_2 will be closed. Current passes from the battery $M\,B$ through key K and relay R to point *i* at the middle of one winding of the repeating coil *a b*. There the current divides equally, one half passing through line *1* and the other half through line *2*, to the point *g*. Here the two currents unite and pass through the relay R_1, the key K_1, and battery $M\,B_1$ to the point *h*, where the current again divides equally, half through line *1* and half through line *2* to the middle point *j* of the repeating coil *e f*. Here again the current unites and passes through the relay R_2, key K_2, battery $M\,B_2$, and the ground to station *A*. If the two sides of the line are equal in resistance, inductance, and capacity, the telegraph current will be equal in lines *1* and *2* and produce no difference of potential between lines *1* and *2* no matter how much the telegraph current may fluctuate. Consequently, no disturbance will be produced in the telephones; thus the telephone instruments will not be disturbed by the telegraph currents. When any one telegraph key is opened, all telegraph relays will open.

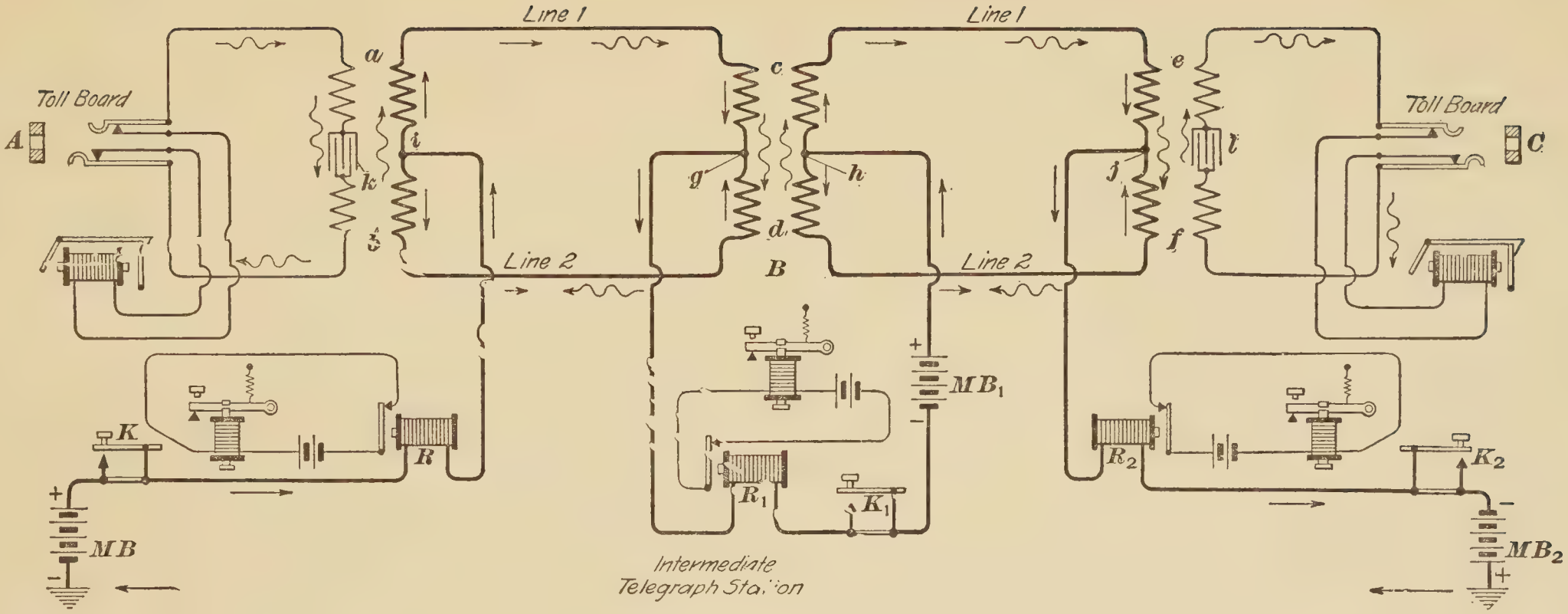
Line 1
Line 1
Toll Board
Toll Board
A
C
a
b
c
d
e
f
g
h
i
j
k
l
Line 2
Line 2
B
K
R
MB
MB1
R1
K1
R2
K2
MB2
Intermediate
Telegraph Station

FIG 7

Fluctuating voice or ringing current in the primary coil of the repeating coil *a b* will induce a difference of potential across the secondary, as a result of which an alternating current will be established in the secondary circuit including the primary of the coil *c d*. By electromagnetic induction in the repeating coil *c d* an alternating current will be produced in the secondary circuit of the coil *c d*. An alternating current will then be induced in the secondary of the coil *e f*, which will affect the telephone devices located at station *C*.

As long as the line is well balanced, there will be little or no telephone current through the telegraph instruments and ground. The use of condensers *k* and *l* in series with the drops is necessary only when the cord circuits have common-battery supervisory signaling. These condensers are omitted if the cords are not arranged for common-battery supervisory signaling.

Where no intermediate telegraph station is desired, it is better to omit the intermediate repeating coil *c d*, lines *1* and *2* being continuous from repeating coil *a b* to repeating coil *e f*. In Fig. 9, one-third of the total number of cells required to operate the telegraph relays are connected in series in the line circuit at each telegraph station. However, a better arrangement is to locate half of the total number of cells at each end station. It is standard practice to have one terminal of all batteries grounded, which permits several circuits to be connected to one battery. An intermediate battery must be separate for each circuit and is therefore expensive.

An intermediate telephone station may be located at any part of the line by simply bridging a telephone set across the line wires. Better results are obtained when the telephone is connected in series with a condenser.

19. Advantages and Disadvantages.—The repeating-coil method has the advantage that regular cord circuits and ringing machines may be used in connecting together two such telephone circuits, without affecting the telegraph apparatus adversely. It has the disadvantage that the introduction of two repeating coils in a circuit causes a distinct loss in the

transmission of both voice and ringing currents; the greater the number of circuits so connected, the greater the loss. Furthermore, in this system, telegraphing may interfere with telephone service in two ways: First, a ground on one wire

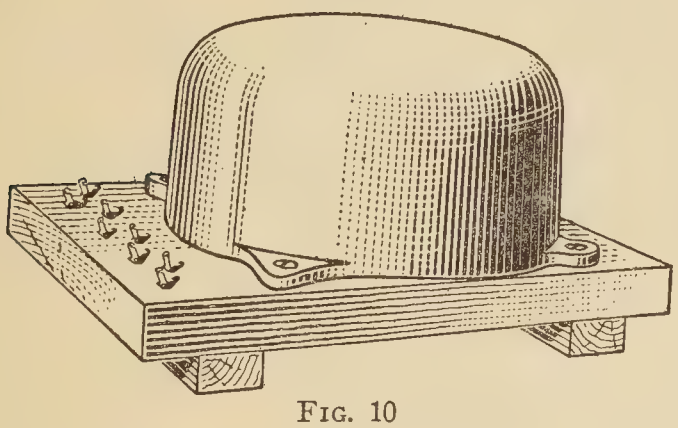

FIG. 10

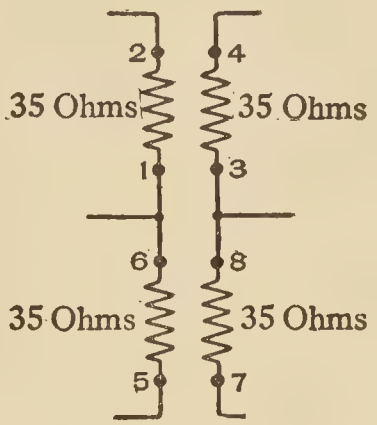

FIG. 11

causes more telegraph current to pass through the corresponding half of the repeating coil, allowing clicks to be heard in the telephone; second, if one wire has higher resistance than the other, as is generally the case to some extent, the current divides unequally, thereby producing a disturbance, which is also noticeable if the repeating-coil windings are not perfectly balanced. It is claimed, however, that before telegraph clicks will be heard in the telephone one wire must have a ground with a low enough resistance to prevent satisfactory telephoning.

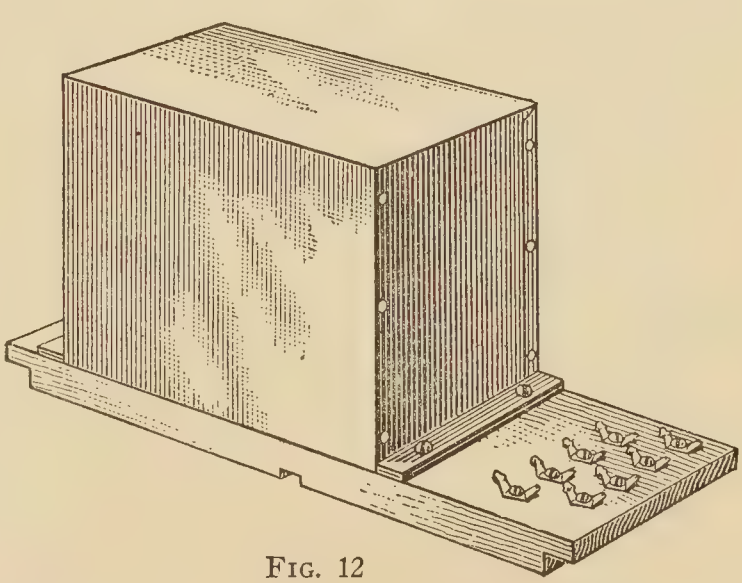

FIG. 12

20. Repeating Coils. The Western Electric Company's ring-shaped 37-A repeating coil, shown in Figs. 10 and 11, having two local windings of 35 ohms and 1,000 turns each, and two line windings of 35 ohms and 2,000 turns each, has an efficiency of about 98½ per cent. for voice transmission and about 97 per cent. when ringing is done with 20-cycle current. The 46-A and 47-A repeating coils resemble the 37-A in general appearance and construction. The 46-A is a double repeating coil,

that is, two complete repeating coils are mounted on one base, with sixteen terminals instead of eight; the 47-A is a single-set repeating coil. The resistance of each of the four windings of such repeating coils is 20 ohms. These coils are much smaller than the 37-A type.

The Kellogg Switchboard and Supply Company's No. 18-A coil, shown in Fig. 12, is very efficient as a ring-through and talk-through coil. The coils of the primary and secondary are parallel-wound. The resistance of each of the coils in the primary winding is 5.7 ohms, while the resistance of each of the coils in the secondary winding is 7.5 ohms. The four windings are concentric wound on a laminated silicon-steel core

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PFUND'S SIMPLEX SYSTEM

21. Pfund's system for simultaneously telephoning and telegraphing over one pair of wires, as shown in Fig. 13, is a combination of impedance and repeating-coil methods. Two line wires form the two sides of the telephone circuit, but for telegraphing they are used in parallel as one side, with the earth as the other side. A repeating coil with equal turns in each winding is required only for the intermediate telegraph station B. Bells a, a_1, and a_2 should have a resistance of at least 1,000 ohms.

The telephone current acting through the repeating coil does not create a difference of potential between points a and a_2, therefore, current will not pass through the telegraph apparatus connected at these points. The middle points of the windings of the repeating coil are also at equal potential. The impedance of each half of bells a or a_2 tends to reduce the rapidity with which the telegraph current rises or falls. No special simplex apparatus is required; the repeating coil and the high impedance bells are the same as are used in telephone systems.

An objection to this plan of using bells for impedance coils is that their magnets are liable to be demagnetized by lightning; also, the bell coils are not well balanced, hence there is the possibility of the telegraph impulses being heard in the telephone receivers.

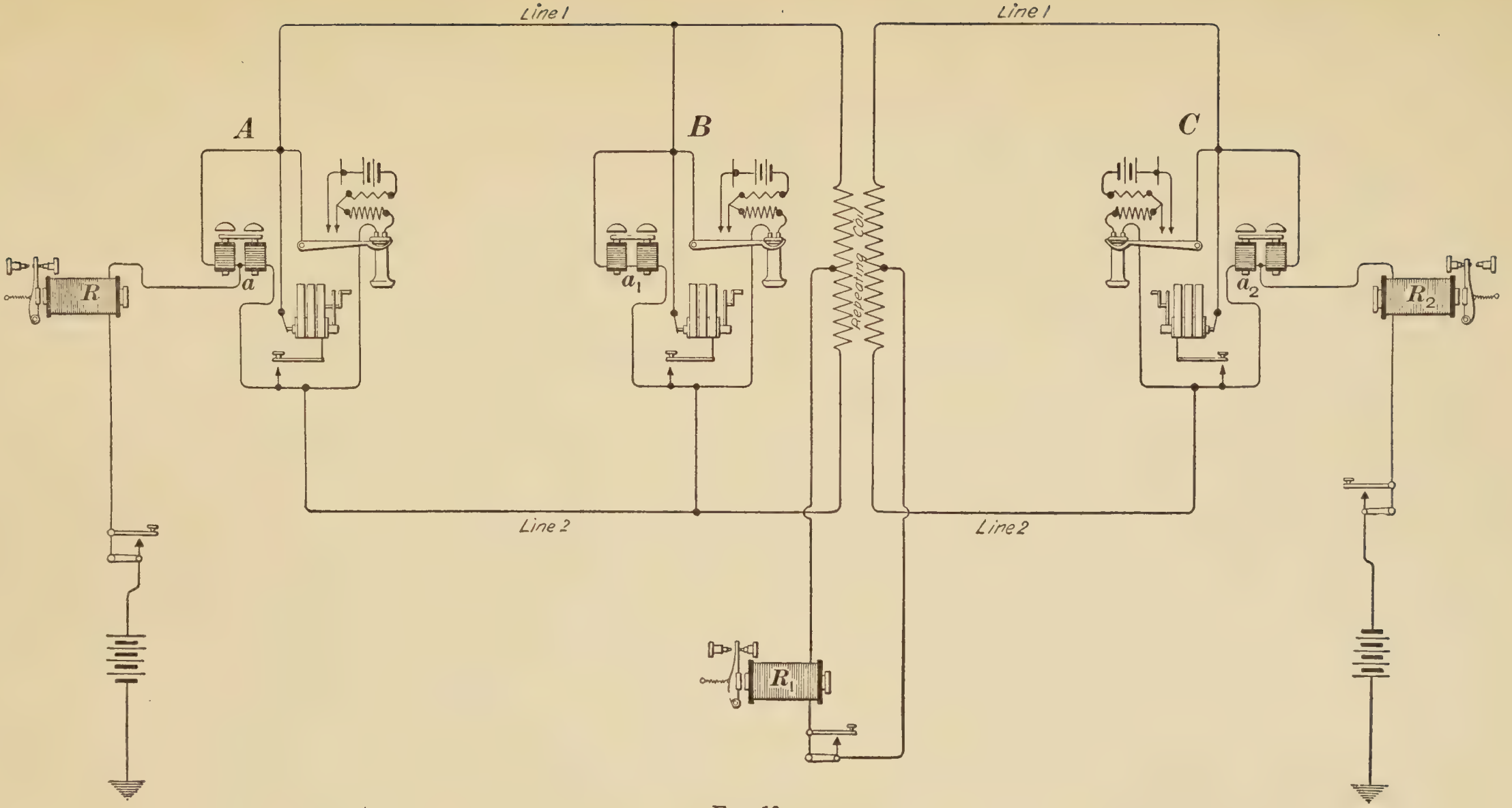

FIG. 13

TROUBLES OF SIMPLEX SYSTEMS

22. The two wires composing a pair used in a simplex system must be of equal resistance, inductance, and capacity to give a quiet telephone. If the resistances are equal, the capacity and inductance of the two wires ordinarily will be sufficiently alike to cause no trouble. A loose connection on one side of the line will increase the resistance of that side considerably; such a condition will cause the telegraph current to pass through the telephone receivers. Should the connection be very loose, the ringing current may cause the relays to chatter. Partial and solid grounds will produce the same effects. Short circuits between the two wires of a simplex line will prevent the proper operation of the telephone apparatus but will not affect the operation of the telegraph apparatus.

TELEGRAPH SYSTEMS FOR USE ON SIMPLEXED TELEPHONE CIRCUITS

23. The telegraph system employed in a simplex system may be any one of the commonly used types. It may be the ordinary single-line Morse, duplex Morse, duplex-operated printing telegraph, single-operated printing telegraph, quadruplex Morse telegraph, and multiplex printing telegraph. No special modifications of the telegraph systems employed are necessary. In the simplex system, however, the two wires forming the circuit have more exposure to trouble than one would have, the capacity is much greater, and there is more leakage in bad weather. The usefulness of such systems is limited, therefore, to a cost figure which is less than that for single straight Morse wires. However, the value of the Morse service gained by simplexing compares favorably with the expense entailed in obtaining it.

COMPOSITE TELEPHONY AND TELEGRAPHY

THEORY OF COMPOSITE CIRCUITS

24. One of the difficulties to be overcome in attempting to telegraph on both branches of an active telephone line, as is done in the composite system, is the prevention of telegraphic signals being heard in the telephone receiver. Unless this is done, much annoyance will be caused those using the telephone; besides, the secrecy of the telegraph will be destroyed. The wasting of the telephone currents in the telegraph instrument must also be avoided.

In a simple, short telegraph circuit, the current will rise to its maximum value almost instantly when the key is closed and fall to zero almost instantly when the key is opened. A curve representing the current in such a circuit is about as shown in Fig. 14. Current values are laid off along the line $O\,X$ and time values along the line $O\,Y$. The time required for the current to reach its maximum value, even on an overhead line of 350 miles in length, is ordinarily less than one-fortieth the time required to make a dot. In telegraphing at the rate of twenty-five words a minute, which is equivalent to about five Morse signals a second, there would be, if means were not taken to avoid it, ten intense clicks every second in a telephone receiver connected between the line wire and the ground, one of these being made every time the telegraph key was closed and another every time it was opened, owing to the very rapid rise and fall of the relatively large telegraph voltage, which may be from about one hundred to one thousand times larger than the telephone voltage. If the telegraph voltage is made to rise and fall gradually enough, the telephone receiver will not make any click. This makes possible simultaneous telephoning and telegraphing over the same wire.

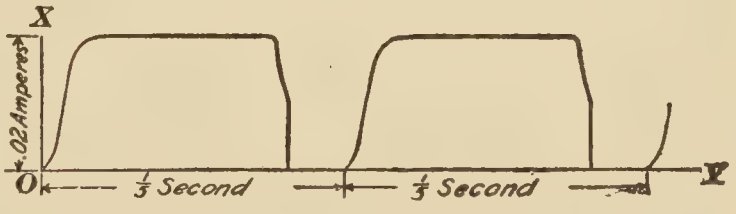

FIG. 14

25. It is a well-known fact that the rise and fall of voltage in a circuit can be delayed, that is, made more gradual by increasing the inductance of the circuit. If, in addition to the inductance, or impedance coil, a condenser is connected

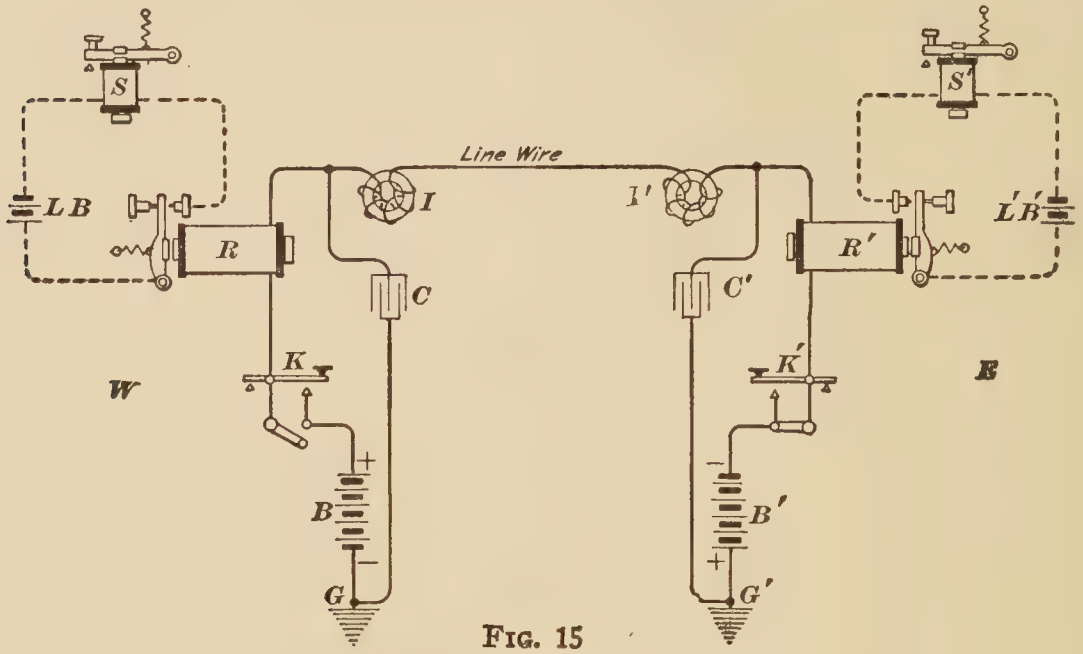

FIG. 15

from the line to the ground, the voltage of the line will rise and fall still more slowly. Hence, by using enough impedance coils and condensers, the voltage of the line may be made to rise and fall as slowly as desired. A simple telegraph circuit in which impedance and capacity is introduced by two impedance coils *I, I'* and two condensers *C, C'* connected in the circuit, is shown in Fig. 15.

The *impedance* coils *I, I'* may consist of a large number of turns of insulated copper wire over a soft-iron wire core, the ends of the iron wire being brought together and overlapped, as indicated in Fig. 16, so as to form a closed iron circuit for the magnetic lines of force. With a given number of turns of insulated copper wire and a given cross-section of iron, such a closed magnetic circuit will give a maximum inductance, causing a maximum opposition voltage to a rapid rise or fall of the applied voltage. In making such a coil, it is of much more importance to have a large number of turns of copper wire and a good magnetic circuit of iron than to have a large resistance. In

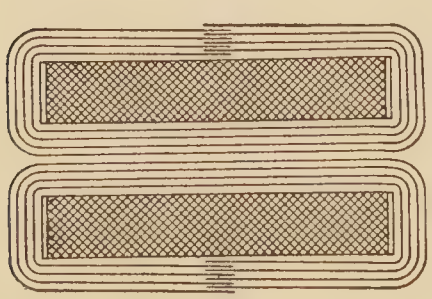

FIG. 16

fact, the smaller the simple, or ohmic, resistance can be kept the better, provided that there is a sufficient number of turns. Low resistance and a large number of turns means a large coil, because large-sized copper wire must be used, and it becomes necessary to compromise in order to have neither too large a coil nor too high a resistance with a given number of turns.

26. When the key *K*, Fig. 15, is closed, the impedance of the relay *R* and of the impedance coil *I* will create a counter electromotive force opposing the impressed electromotive force, and this force will act as a cushion to the applied voltage and will prevent it from attaining its maximum strength as quickly as it would if the impedance coil *I* were not in the circuit. The greater the inductance in the circuit, the slower will be the rate of increase or of decrease of the voltage. The counter electromotive force of the coils becomes zero when there is no further cutting of magnetic lines of force, at which time the applied voltage has full effect, and the current in the circuit then follows Ohm's law. Current in the relay *R* divides between the path through the condenser *C* and the path through the coil *I*, and as the condenser becomes more and more nearly charged to its full capacity, more current will pass through the coil *I*. The condenser charging current in passing through relay *R*, or *R'* increases the rise of magnetism therein. The increased counter electromotive force in the relay, due to the sudden increase in lines of force, opposes the applied voltage and delays the arrival of the steady state of the line current. The charging current ceases when the current in the line reaches its steady state. The increase in the strength of the line current is thus made to take place more gradually than it would without the condenser and the impedance coil.

When the key *K* is opened, the condenser *C* tends to discharge through the coil *I* into the line in the direction of the original current, thereby tending to prolong the current in the line and causing it to decrease more gradually. The magnetic field which has been built up in coil *I* also tends to continue the current in its original direction, as this field collapses when the

key K opens. The combination of condensers and impedance coils thus opposes any rapid change in the strength of the current, and by using the proper amount of inductance and capacity the current curve can be made to approach that shown in Fig. 17.

27. At the rate of twenty-five average five-letter words a minute, there would be about five dots and spaces, or five curves like the two shown in Fig. 17, a second. The impedance coils and condensers will interfere with telegraphing at a high speed, and especially with rapid automatic and printing telegraph systems, because the signals will be of such short duration that there may not be time for the current to rise or fall through a sufficient range to operate the relays properly. About the lowest audible sound is produced by sixteen complete vibrations per second; therefore, an undulating current that changes at such a low rate that it will not cause the diaphragm of a telephone receiver to move as fast as it will be moved by a current having a frequency of sixteen periods per second, will produce no sound in the receiver.

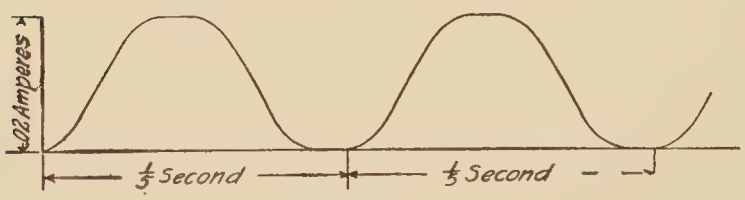

FIG. 17

To make the rise and fall of the telegraph voltage gradual enough so as not to affect the telephone receiver, two impedance coils I, I_1 and two condensers C, C_1 may be associated with the line circuit as shown in Fig. 18. In order that as much as possible of the current of the telegraph signal made at the sending station shall affect the relay at the receiving station, it is necessary to limit the leakage of the telegraph current through the receiver. To accomplish this, the condenser C_2 is connected in series with the telephone receiver $T\,R$ and the secondary winding s of the telephone induction coil. The condenser will not allow a continuous current to pass through it, because its resistance to such a current is very great. The condenser charges and discharges very slowly when telegraph signals are being sent, thereby causing the receiver diaphragm to receive a pull of short duration toward the magnet by each impulse through

the condenser C_2 when the key is closed. When the key is opened, the condenser discharge will cause the diaphragm to recede somewhat from the magnets for a short period. The diaphragm is normal between the current impulses, each one of which may be considered as giving the diaphragm a slight and gradual pull. The effect on the diaphragm is only transient during the time condenser C_2 is either charging or discharging. The rate of change of the current in the receiver under these conditions is not great enough to cause an audible sound.

28. It has been shown that the telegraph signals, if their rise and fall is gradual enough, do not disturb the telephone receivers. It yet remains to be shown that the telephone cur-

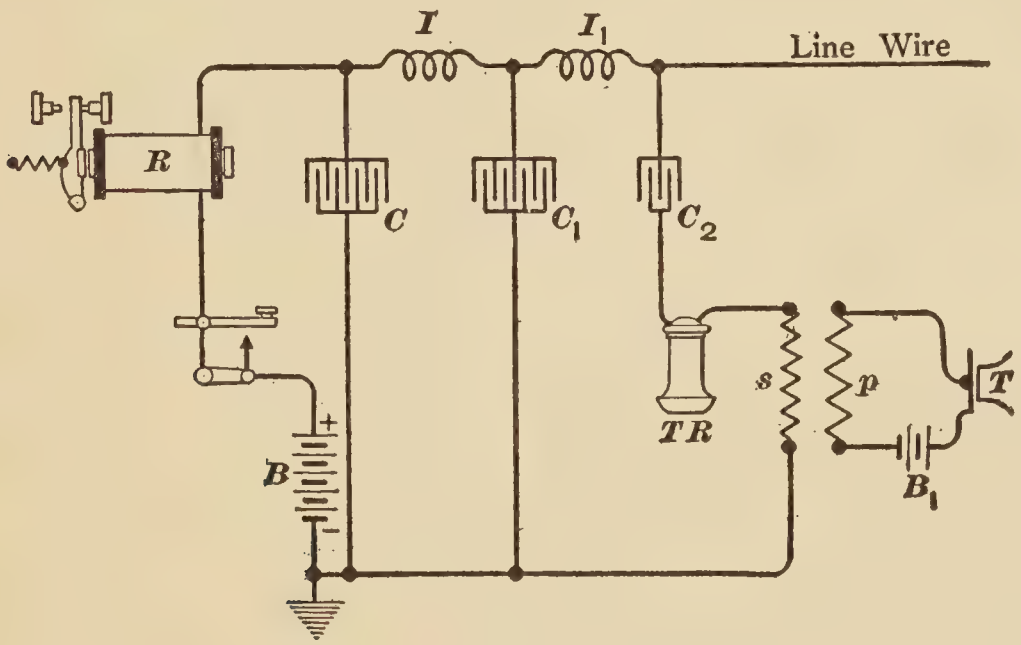

FIG. 18

rent sent from one end will operate the telephone at the other end, but will not interfere with the telegraph signals sent from either end.

By talking into the telephone transmitter T, Fig. 18, which is connected to the primary coil p, an alternating electromotive force is generated in the secondary winding s of the induction coil, the average frequency of which is at least 300 periods per second. This rapidly alternating electromotive force will charge and discharge the condenser C_2, thereby producing in the line wire an alternating current similar to that in an ordinary telephone line. Fig. 19 represents such a current wave as might be produced in the line wire by the simplest sound waves

having a frequency of 300 periods per second. Let the curve *A*, Fig. 20, represent the slowly increasing and decreasing telegraph current, and the curve *B* the rapidly alternating telephone current. In the receiver circuit the voice current will be superimposed upon the condenser-charge current due to the telegraph-current wave and the result will be similar to curve *C*.

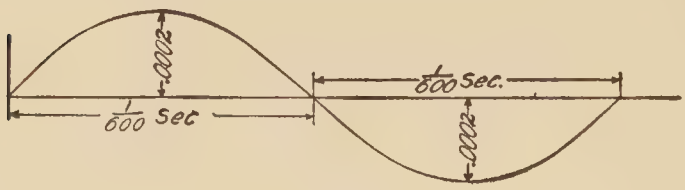

Fig. 19

When both the telephone and telegraph are in simultaneous operation, the telegraph current may cause the diaphragm of the receiver to move in and out through a relatively large amplitude, but too slowly to make any sound. At the same time it will vibrate very rapidly through a very small amplitude, because the telegraph current will have its strength very rapidly, but very minutely, increased and decreased by the telephone current. It is enough, nevertheless, to increase and decrease the pull of the magnet on the diaphragm sufficiently to produce sound waves. One vibration is thus superimposed on the other, and the diaphragm vibrates, or trembles, very rapidly as it moves slowly in and out as the telegraph current changes strength, and it reproduces the words spoken at the distant transmitter, but the telegraph current produces no sound.

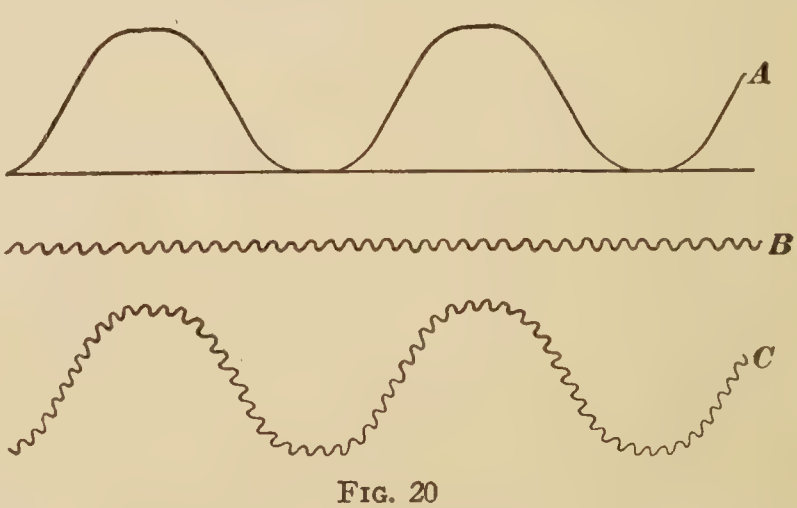

Fig. 20

29. Practically all the telephone current will go over the line and through the distant receiver, for the reason that a circuit containing inductance offers more opposition to alternating current than the simple resistance with which it opposes a direct current, and this opposition increases very rapidly as the frequency increases. For instance, a certain impedance coil, with a resistance of 500 ohms and an inductance of 8 henrys, offers an impedance of 15,128 ohms to an

alternating current whose frequency is 300 periods per second. This impedance is over thirty times as large as the simple resistance.

The impedance of a telephone circuit, including a 60-ohm receiver, a 250-ohm secondary coil, and a 2-microfarad condenser, does not exceed about 415 ohms. An induction coil having a lower resistance secondary, such as the 14-ohm coil used by the Bell Companies on their long-distance lines, would be better in this case. In circuit with the impedance coil there is also the telegraph relay, so that the total impedance of a 500-ohm, 8-henry impedance coil, and a 150-ohm, 5-henry telegraph relay at one end of the line circuit is at least fifty times as great as that of one receiver circuit. Consequently the incoming high-frequency voice current will divide in the ratio of the impedances, and the greater part of it will go through the telephone receiver circuit. Only a very small part of the telephone current will pass through the impedance coils and the telegraph relays and this will not be strong enough to operate them and thus interfere with telegraph operation. To insure more satisfactory results, two impedance coils and two condensers may be used at each end, as shown in the *Van Rysselberghe composite system,* thus compelling practically all the telephone current to pass through the line and the distant telephone circuit.

VAN RYSSELBERGHE COMPOSITE SYSTEM

30. Circuit Connections.—A composite system for the simultaneous transmission of telephone and telegraph messages over the same line was originated and developed by Mr. J. F. Van Rysselberghe, an official of the Belgian telegraph service. The principles just explained are involved in this and other composite systems.

The complete arrangement of the Van Rysselberghe simultaneous telephone and telegraph system is shown in Fig. 21. This figure gives a diagram of connections for one complete metallic telephone circuit and two telegraph circuits over one pair of line wires, the ground being used as a return for the two telegraph circuits.

If a completely closed magnetic circuit of good soft iron is used for the impedance coils *I*, enough turns of insulated copper wire to make 50 ohms have been found to be sufficient for each coil. If desirable, an ordinary telephone annunciator may be used, as shown at *D, Station 2*, in place of the bell shown at *Station 1*.

31. The push button, which normally short-circuits the generator armature, Fig. 21, must be pressed when the generator handle is turned to call up the distant station. Most generators have an automatic device that accomplishes the same purpose when the handle of the generator is turned. When the receiver is on the hook *H*, the bell and generator are connected across the two line wires through the condenser. The circuit containing the primary winding *P* of the induction coil, the transmitter *T*, and the transmitter battery B_1 is open, and the circuit containing the telephone receiver *T R* and the secondary winding *S* is short-circuited. When the receiver is removed from the hook, the bell and generator are short-circuited, the local transmitter circuit is closed, and the short circuit around the receiver and secondary is opened, leaving the local transmitter circuit closed through the condenser across the two line wires.

32. Telegraph Relays and Batteries.—Relays of at least 150-ohm resistance may be used, and half the total number of cells necessary for operating the telegraph instruments should be placed at each end, the two batteries being in series with each other. In the long-distance exchanges of the Bell Companies, the current required for nearly all purposes is supplied by storage batteries. Possible interruption to the service, due to a failure of the source of power used to charge the batteries, is guarded against by reserve supply mains or by emergency generators driven by gasoline engines.

33. Ringing Difficulty.—With the Van Rysselberghe arrangement, Fig. 21, it is difficult to ring the distant telephone bell, because some of the ringing current, being of nearly the same frequency as the telegraph impulses, can pass to ground

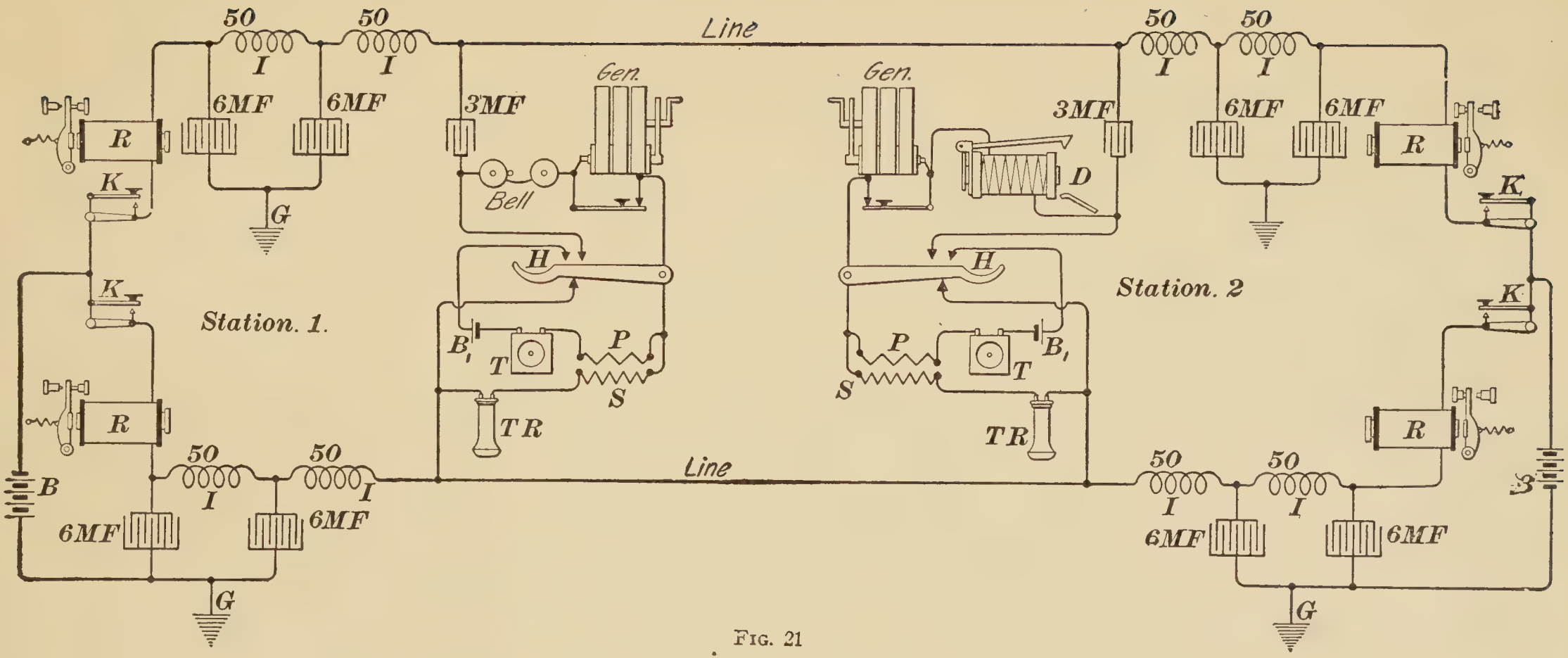
50
50
I
I
Line
6MF
6MF
3MF
Gen.
R
K
G
Bell
H
Station. 1.
B1
T
P
S
TR
B
Station. 2
D

FIG. 21

through the impedance coils and telegraph relay at the end where the ringing current is applied. Moreover, this current is apt to make the telegraph relay chatter. To avoid this difficulty, it was customary at one time to use one of the two telegraph circuits for signaling purposes. Each end of one telegraph line would be connected through a relay to ground and a key would be arranged so that, when closed, a battery would be cut in the circuit in place of the relay. The local circuit of the relay at each end would include a drop and the exchange ringing generator. Thus, closing the key at one end would cause the distant relay to attract its armature, thereby closing the circuit containing the drop and the constantly running generator at the distant exchange. The falling of the drop shutter would attract the attention of the operator, who would in the usual way connect her telephone set across the line and reply through it.

34. Grounded Composite.—In some localities where earth currents are not troublesome and where there is no inductive interference from other lines, it is practical to telephone and telegraph simultaneously over one line wire, no second line wire being at all necessary. To do this, the following changes should be made in the arrangement shown in Fig. 21: The two main-line telegraph batteries *B* and the lower ends of the two telephone sets should be directly grounded, and the two lower telegraph sets (one at each end, including the two adjacent impedance coils and the two condensers) and the lower line wire should be omitted.

35. In composite telephone and telegraph systems, one telephone and two telegraph messages can be sent simultaneously over one pair of line wires, the earth being used as a return path only for the two telegraph currents; or, by using the earth as a return for the telephone as well as for the telegraph current, then over a single wire, one telephone and one telegraph message may be transmitted simultaneously. In simplex telephone and telegraph systems, however, the two line wires in parallel are required for one side of one telegraph circuit, the ground forming the other side, and hence only one

telegraph and one telephone message can be transmitted simultaneously over two line wires, including the ground as a return for the telegraph circuit.

BELL COMPOSITE SETS

36. Circuit Connections.—There are several plans of wiring details of composites which are more or less successful. The system that has been employed by the American Telephone and Telegraph Company is illustrated in Fig. 22, in which is shown the apparatus at two exchanges with one pair of line wires connecting them. The letters B, B_1, B_2, and B_3 represent the Morse batteries for operating the telegraph circuits; $D\,c$, $D\,c_1$, $D\,c_2$, and $D\,c_3$, differentially connected retardation coils; and $S\,c$, $S\,c_1$, $S\,c_2$, and $S\,c_3$, series-connected retardation coils. The connections at the two terminal stations are identical, except that opposite terminals of the Morse batteries are grounded. If storage batteries are used, one battery at each end connected in the ground taps at a and b, or one battery connected in either ground tap at a or b, may serve both telegraph circuits.

37. Each differentially connected retardation coil $D\,c$, $D\,c_1$, $D\,c_2$, and $D\,c_3$, Fig. 22, consists of two windings, the total resistance of which is 50 ohms. The two windings are differentially connected so that a current in the two windings tends to magnetize the one iron core, on which they are placed, in opposite directions; hence, it is called a *differentially connected coil.* Each series-connected retardation coil $S\,c$, $S\,c_1$, $S\,c_2$, and $S\,c_3$ consists of two windings having a total resistance of 30 ohms and connected so that both windings tend to magnetize the one core in the same direction; hence, it is called a *series-connected coil.* When a direct current passes through a differentially connected coil of the type shown in Fig. 23, the magnetizing effect of one winding opposes that of the other winding, and the resultant magnetic lines of force will be leakage lines through the air from one end of the coils to the other. The inductance in this method of connection for telephone currents will be but five-eighths that of the retardation coil in which

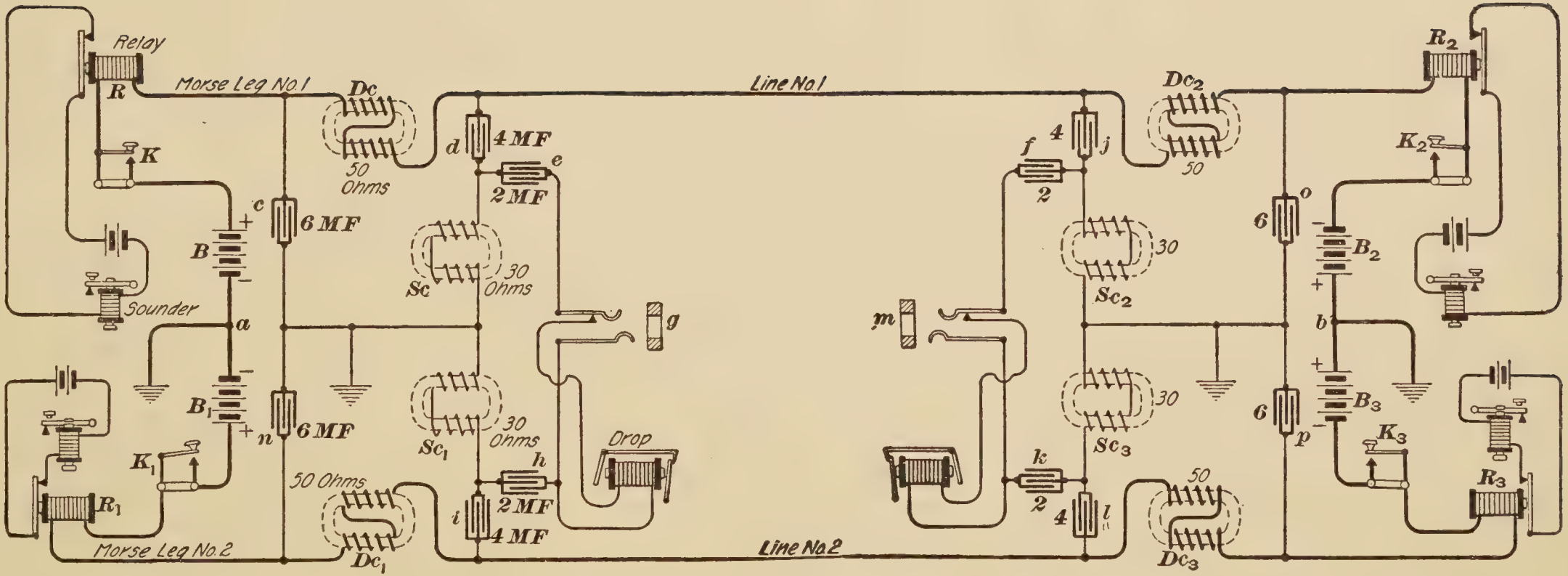
Relay
R
Morse Leg No.1
Dc
50 Ohms
Line No.1
Dc2
50
R2
K2
K
d
4 MF
e
2 MF
c
6 MF
B
Sc
30 Ohms
Sounder
a
g
m
f
4
j
2
30
Sc2
o
6
B2
b
B1
n
6 MF
Sc1
30 Ohms
Drop
h
i
2 MF
4 MF
K1
R1
50 Ohms
Dc1
Morse Leg No.2
Line No.2
k
2
4
l
Sc3
p
B3
K3
R3
Dc3

FIG 22

the magnetizing effects of the two windings aid each other. The lesser inductance of the differential retardation coil is sufficient to prevent current at voice frequencies from passing through the Morse legs. The inductance of these coils for telegraph currents will also be sufficient to round off the Morse voltage waves.

38. Operation.—If the operator at key *K*, Fig. 22, is sending, a pulsating current of low frequency will pass from battery *B* through key *K*, relay *R*, *Morse leg No. 1* to the coil *D c*. The sharp points of the voltage curve will be rounded off, that is, the voltage will be more like a smooth sine curve, as shown in Fig. 17, a result of the inductance of *D c* and the capacity of the condenser *c*, Fig. 22. The current that passes through the coil *D c* being at low frequency, will follow *Line 1* and operate the distant Morse relay R_2. That part of the current impulse which will pass through the condenser *d* will pass largely to earth through the retardation coil *S c*, and is further minimized in the telephone circuit by the condenser *e*. Condenser *f* serves the same purpose at the other end of the line. Coils *D c* and *S c* may be termed *frequency filters*, because they permit current at one frequency to pass quite readily, but effectually block current at different frequency.

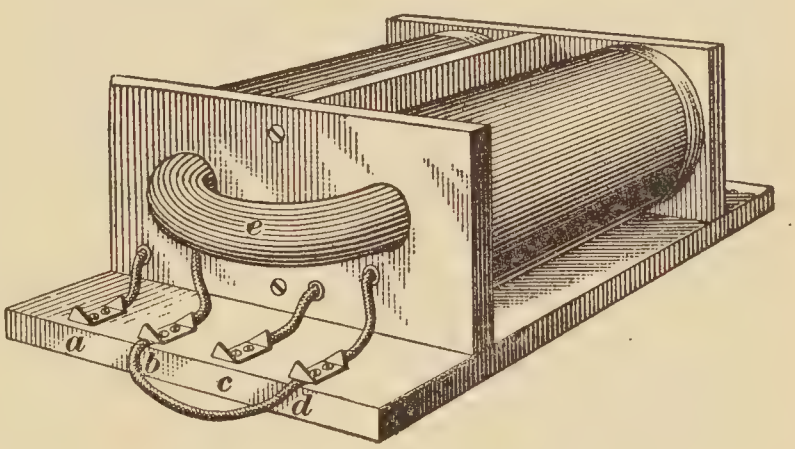

FIG. 23

39. Consider the telephone circuit in Fig. 22. The telephone current enters the circuit by way of jack *g* and being of high frequency, readily passes through the condensers *e* and *h*, but is blocked in the coils *S c*, $S\,c_1$ by their high impedance. The current then passes through the condensers *d* and *i*, but is kept out of the Morse legs by the impedance of the coils *D c*, $D\,c_1$; therefore, the telephone current passes out on the line to the distant exchange. Here, again, it is kept out of the Morse

legs by the coils $D\ c_2$ and $D\ c_3$, but it finds passages through the condensers *j* and *f*, and *k* and *l* to the jack *m*.

The greater the capacity of a condenser, within certain limits, the more efficient it is for transmitting voice currents, but experience shows that if too large condensers are used at *e*, *h*, *f*, and *k*, a perceptible disturbance is produced by the telegraph current in the telephone, owing to the larger charge and discharge currents in these condensers, as the potential in the telegraph line rises and falls when a telegraph key is opened and closed.

Thus the Morse current is kept out of the telephone circuit; the Morse current from one leg cannot reach the other leg; and the telephone current is confined to its proper circuit.

40. Coils.—The Western Electric 5-L 50-ohm differentially connected coil is shown in Fig. 23. It is wound with No. 20 single cotton-covered wire. The four terminals are shown at *a*, *b*, *c*, and *d*. A 30-ohm series-connected coil is made in the same style and with the same dimensions, but is wound with No. 18 single cotton-covered wire and has clips *b*, *c* connected together instead of *b*, *d*. The core *e* consists of a bundle of annealed Norway-iron wires, about No. 25 B. & S., from $1\frac{1}{2}$ to 2 inches thick. The coils are wound on wooden spools; the bundle of iron wires is bent in the form of a **U** and passed through the spools, and the ends are interlaced and tied with iron binding wire.

41. One adverse characteristic of the composite set lies in the fact that there is much capacity to ground through the condensers *c*, *n*, *o*, *p*, Fig. 22; these condensers must be charged as the current is entering the line. This results in a *heavy line*, by which is meant that the sounder does not respond instantly to the touch of the key. This condition is annoying to experienced Morse operators, but, for general use, the composite circuit is successful, and is able to compete with the straight Morse circuits. The drops shown in Fig. 22 may be replaced by relays which are more sensitive, and which may be used to close circuits containing drops or lamps.

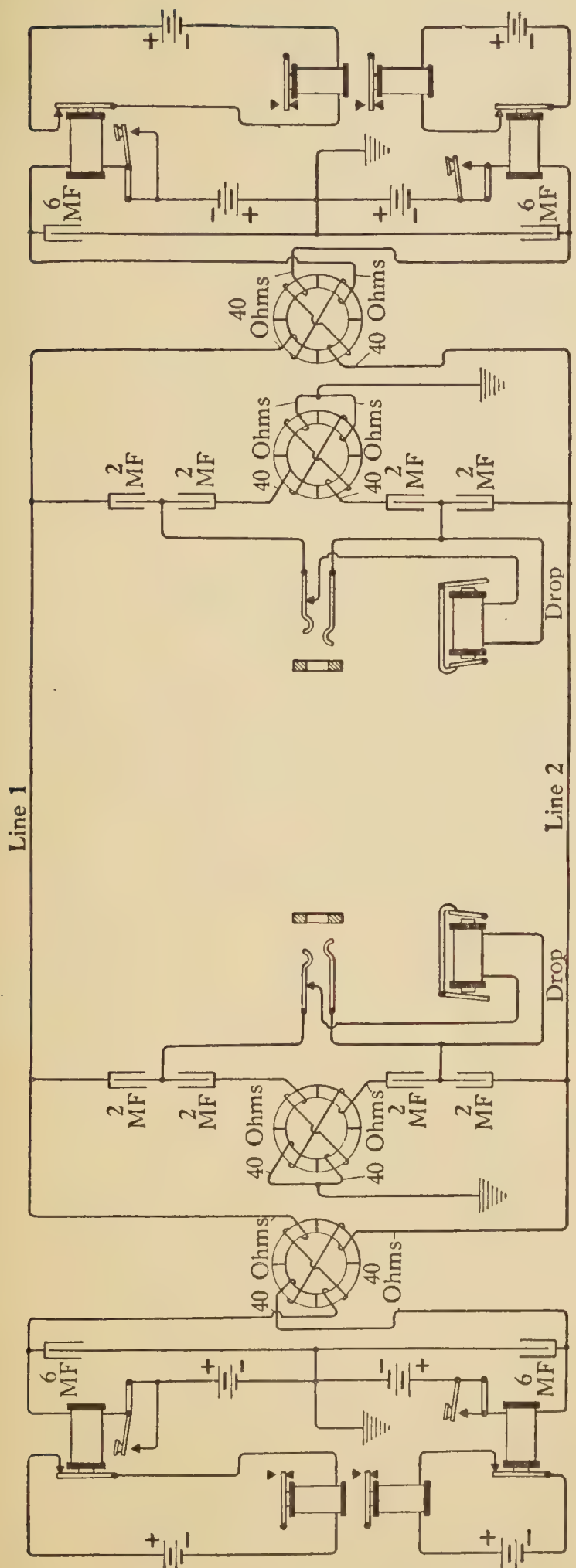

FIG. 24

MODIFIED BELL COMPOSITE SET

42. A composite circuit that is extensively used by the American Telephone and Telegraph Company is shown in Fig. 24. It is a modification of the circuit shown in Fig. 22. It will be noted that only one coil is used for both Morse legs at either end; also only one coil is used in the telephone circuit at each end. The condensers have been removed from the drop circuit to the shunt coil circuit. The set thus requires but four coils instead of eight as in Fig. 22.

The design of the coil is radically different from that shown in Fig. 22. The four windings, Fig. 24, are on a circular core imbedded in a resin compound, with a punched sheet-iron cover. The coils are so constructed that current through one telegraph

circuit does not induce voltages in the other telegraph circuit. The two windings in one telegraph circuit of the differential coil are electrically separate from the two windings of the other telegraph circuit.

INTERMEDIATE COMPOSITE SETS

43. When intermediate stations are cut in, and terminate the telephone as separate circuits from each direction, and the Morse circuits go through from one terminal station to the other, the sets of Figs. 22 and 24 must be somewhat modified. The 6-microfarad condensers are replaced by 1-microfarad condensers; as, in this case, when two sets are connected, the capacity will be 2 microfarads (1 microfarad in each set) which is

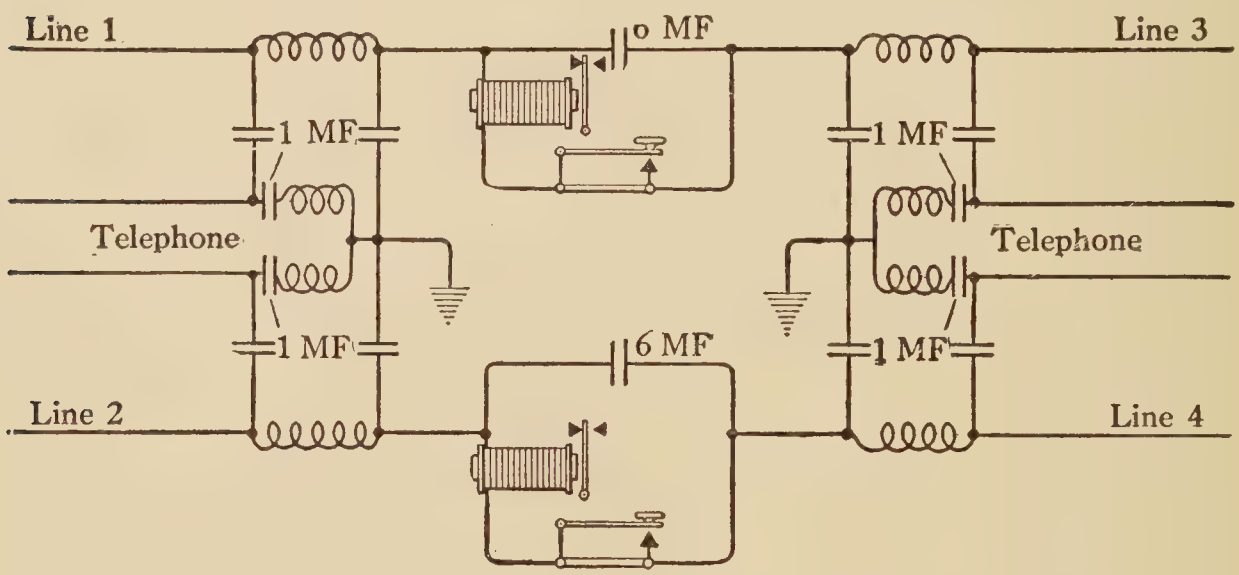

FIG. 25

sufficient, as the sets are a considerable distance from the points where the battery of the Morse circuit is being opened and closed. The voltage variation at this intermediate station is, therefore, reduced by the distance from the battery to such an extent that 2-microfarad capacity is sufficient to round off the waves and prevent them from being detrimental to the telephone side of the circuits.

If the telegraph set is cut in at this intermediate station, it is necessary to bridge a condenser of 6-microfared capacity across the intermediate telegraph set as shown in Fig. 25. This arrangement will modify the waves and prevent the telegraph signals from being heard in the telephone receivers.

COMPOSITE RINGING APPARATUS

44. Reason for Special Apparatus.—The ordinary twenty-cycle generator can not be used for ringing purposes on composited lines on account of its low frequency. A current of this frequency will pass through the retardation coils and interfere with the proper working of the Morse instruments. To overcome this difficulty it is necessary to use a current of such a frequency that it will not pass through the retardation coils, but will operate the signaling apparatus of the telephone circuits at the distant end. This result is obtained by using composite ringing apparatus.

45. Relays for Low- and High-Frequency Alternating Currents.—In the operation of composite ringing systems it is necessary to have relays that will respond to the low frequencies of a ringing generator, and other relays that will operate

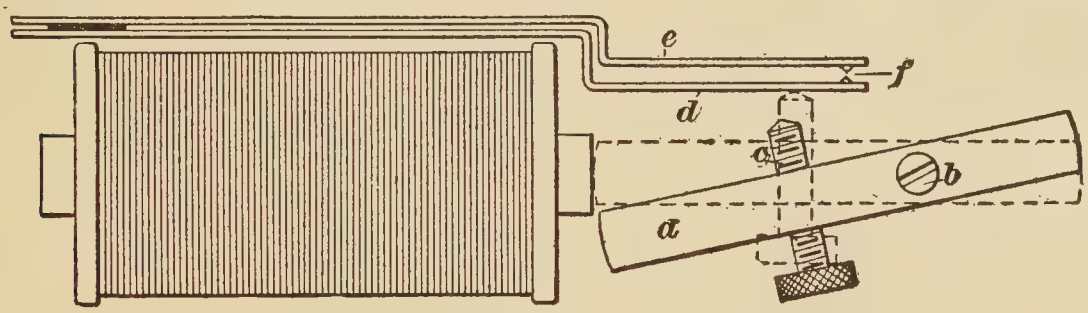

FIG. 26

on currents of higher frequencies. The principle of operation of a low-frequency alternating current relay may be explained in connection with Fig. 26. The coil is so wound that it will permit alternating currents of low frequency to pass through it. Reversals of current in the coil will cause reversals of magnetism in the core. When the current is in one direction, the iron armature *a* will swing on its pivot *b*, and assume a horizontal position in line with the core of the electromagnet. The screw *c* is so adjusted that when the end of the armature near the coil moves upwards, the point of the screw presses against the lower of the two contact springs *d* and *e*, and closes the contact at *f*. When the direction of the current in the coil is about to reverse, the magnetism in the core is zero; at this moment the end of the armature near the coil has a tendency

to move downwards, but owing to its construction it is rather sluggish in this operation. Thus before the armature is moved sufficiently to open the contact between *e* and *d*, current is again established in the coil, and the contact at *f* is preserved.

46. A relay that will respond to high-frequency alternating currents is shown in a conventional manner in Fig. 27. This relay operates on the principle of a polarized relay. The two coils *a* and a_1 are placed on the poles of two permanent magnets and are connected in such a way that current passing through the coils tends to weaken the magnetism of one of the magnets and strengthen that of the other. This relay has two armature springs *b* and *c*, set in the same plane; in the illus-

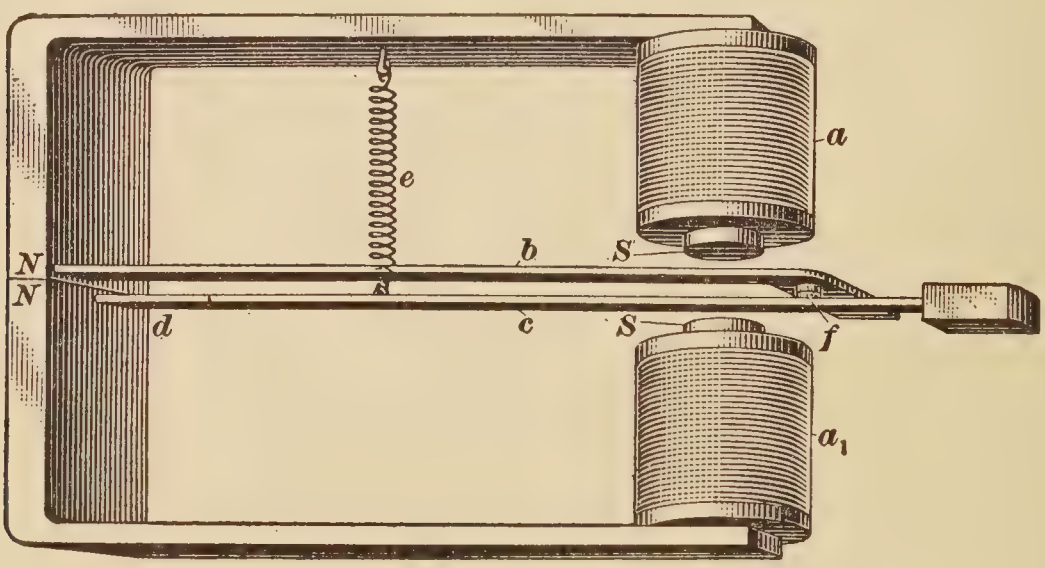

FIG. 27

tration, however, one is shown a little offset in order that the contacts may be seen clearly. The springs are secured near *d* at the left-hand ends of the two permanent magnets and extend beyond the poles of the electromagnets. When there is no current in the coils, the iron armature *b* would be attracted equally by each pole, were it not for the action of the retractile spring *e*, attached to the non-magnetic armature *c*, which tends to draw the armatures *b* and *c* nearer one pole than the other and to close the contacts between the armature springs at *f*. The iron armature spring *b* is so light that when an alternating current is passed through the coils, it will vibrate or move very rapidly from one pole to the other. The non-magnetic armature *c* will not be affected directly by the electromagnets, but

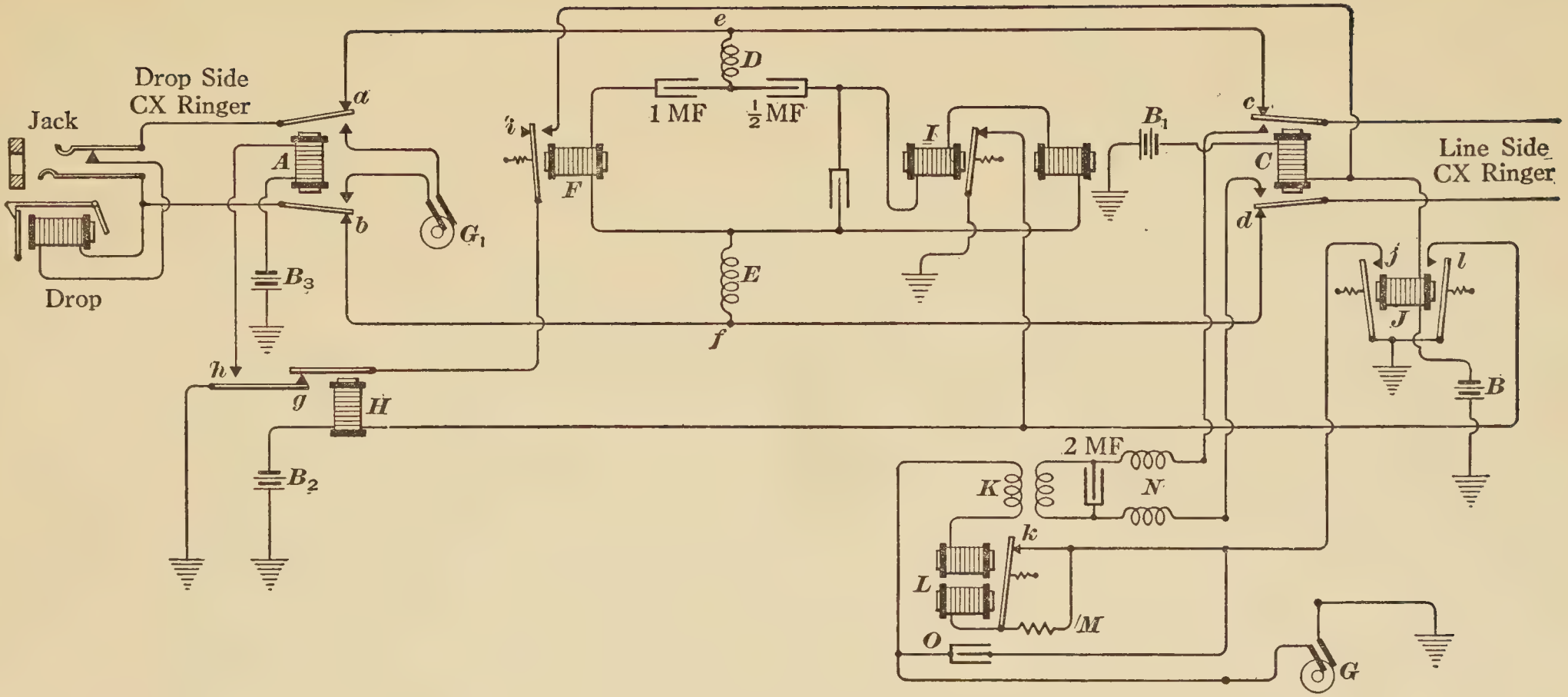
Drop Side
CX Ringer
Jack
Drop
a
A
b
G_1
B_3
e
D
1 MF
½ MF
i
F
E
f
I
B_1
c
C
d
Line Side
CX Ringer
j
J
l
B
h
g
H
B_2
2 MF
K
N
k
L
M
O
G

FIG. 28

will vibrate due to the action of the retractile spring *e*. There is such a great difference between the natural rates of vibration of the two armature springs, however, that the contact *f* between them is for practical purposes considered as being open when the electromagnets are energized.

47. Bell Telephone Company's Composite Ringing Circuits.—A type of composite ringing circuit used by the Bell Telephone Companies and known as Type A is shown in Fig. 28. The drop side of the toll line is connected to the spring contacts of a relay *A*, and when this relay is not energized, the circuit is closed to the line side through the outer contact points *a*, *b*, *c*, and *d* of the relays *A* and *C*. This is the normal condition of the circuit during conversation. Should the operator wish to call the distant office, she inserts a plug in the jack and throws the regular ringing key of the cord circuit in the usual manner, sending current from the generator, through the armature of relay *A*, to the points *e* and *f*, where a shunt circuit is formed through the coils *D* and *E*, the condensers, and the relay *F*. This relay, also shown in Fig. 26, is so designed that a low-frequency alternating current, such as is furnished by an ordinary ringing generator will operate it; relay *F* is, therefore, operated. Relay *H* is energized by current from battery B_2 through the winding of relay *H* and through the closed contacts of relay *I* to the ground. The armature of relay *H* is held against its magnet and connected to the ground through contact *g*. At the same time contact *h* of the circuit including relay *A* is held open. The armature of relay *F*, which is now closed against its contact *i*, is connected to the ground through contact *g* of relay *H*. Current from battery *B* now energizes relay *J* and passes to the ground through contacts *i* and *g*. Relay *C* is energized by current from battery B_1 through the winding of relay *C* and contacts *i* and *g* to the ground. The closing of contact *j* of relay *J* completes a circuit containing a ringing generator *G*, the primary winding of the repeating coil *K*, and a specially designed interrupter *L*, the vibrating armature of which is shunted by a 20,000-ohm non-inductive resistance *M*. As long as the circuit remains

closed at *j*, the armature of *L* will vibrate. The closing of the relay *C* connects the secondary winding of the repeating coil *K* across the line through a modulating coil *N*.

The action of the interrupter *L*, starting with it energized and the vibrator making contact at *k*, is as follows: The alternating current from the generator *G* energizes coil *L* and the circuit is opened at *k*, thereby connecting the resistance *M* in series with coil *L* and reducing the current so much as to cause coil *L* to release its armature, thus closing the circuit again at *k*, in which position the resistance *M* is short-circuited. This operation continues as long as the circuit remains closed at contact *j*. The non-inductive resistance *M* connected around the contact *k* reduces the sparking at *k* without interfering with the operation of the interrupter *L*. The vibrator is so constructed that about six and three-quarters interruptions or pulsations are produced for each cycle, or period, of the alternating current; hence, the frequency of this current becomes six and three-quarters times that of the alternator. Thus if the generator current has a frequency of 20 cycles per second, the interrupter produces 135 cycles per second. This high-frequency current produces, by induction through the repeating coil *K*, a current of similar frequency in the line, but this current does not interfere with the Morse working. The condenser *O* is used to form a path for the high-frequency discharge from the interrupter *L* and thus keep it out of the generator *G*. It is customary to use one interrupter with as many as five relay equipments. The contact *l* of relay *J* is connected in parallel with the armature of relay *I*. The armatures of relay *J* are closed whenever relay *F* is operated by the home operator ringing out. Should the relay *I* be operated when ringing current is sent out, the closed contact *l* of relay *J* prevents the opening of relay *H*, which if opened, would close the circuit of generator G_1.

48. Suppose that Fig. 28 now represents the connections at the receiving office; the high-frequency current coming from the distant office passes through the springs and outer contacts *c* and *d* of the relay *C* to the points *e* and *f*. From *e* this

current passes through the coils *D* and *E*. The division of current at *D* and *E* through relays *F* and *I* is unequal, owing to the high impedance of relay *F* to high-frequency currents. The relay *F* will not permit enough of this high-frequency current to pass through and operate this relay. The greater portion of this current passes, therefore, through relay *I* also, shown in Fig. 27. This relay is designed specially to operate on such high frequencies. The attraction of the armature of relay *I*, Fig. 28, will open the circuit containing battery B_2 and relay *H*. In consequence, relay *H* releases its armature, thereby closing the circuit containing contact *h*, relay *A*, and battery B_3. The relay *A* then attracts its armature and thus connects the ringing generator G_1 across the drop side of the composite set, which causes the drop to operate. The Morse apparatus being cut off at contacts *a* and *b*, which are now open, the current from *G* cannot affect its working. Relay *H* is denergized and its contact *g* is held open by a spring while the incoming high-frequency current causes the contact of relay *I* to chatter. This action prevents the circuit of relay *C* from being closed and the false operation of relay *C*, which would occur if relay *F* were adjusted delicately enough to operate on the high-frequency current and the contact at *g* were to remain closed.

49. While the composite ringer seems like a very complicated piece of wiring, it is really only a buzzer-like contrivance arranged to furnish a current that has too high a frequency and too small an amplitude to affect the Morse instruments, while the delicate 300-ohm polarized relay responds to these rapid impulses.

Composite-ringer interrupters are at some offices replaced by an alternating-current generator of a frequency of 135 cycles. In offices not supplied with a generator or an interrupter, a number of dry cells, though preferably caustic-soda primary cells, connected in series with the primary of an induction coil and a stiff-springed, closely adjusted buzzer, serve the purpose of producing the high-frequency current; but the current from the secondary, of course, is alternating and of much higher voltage than that of the cells in the primary.

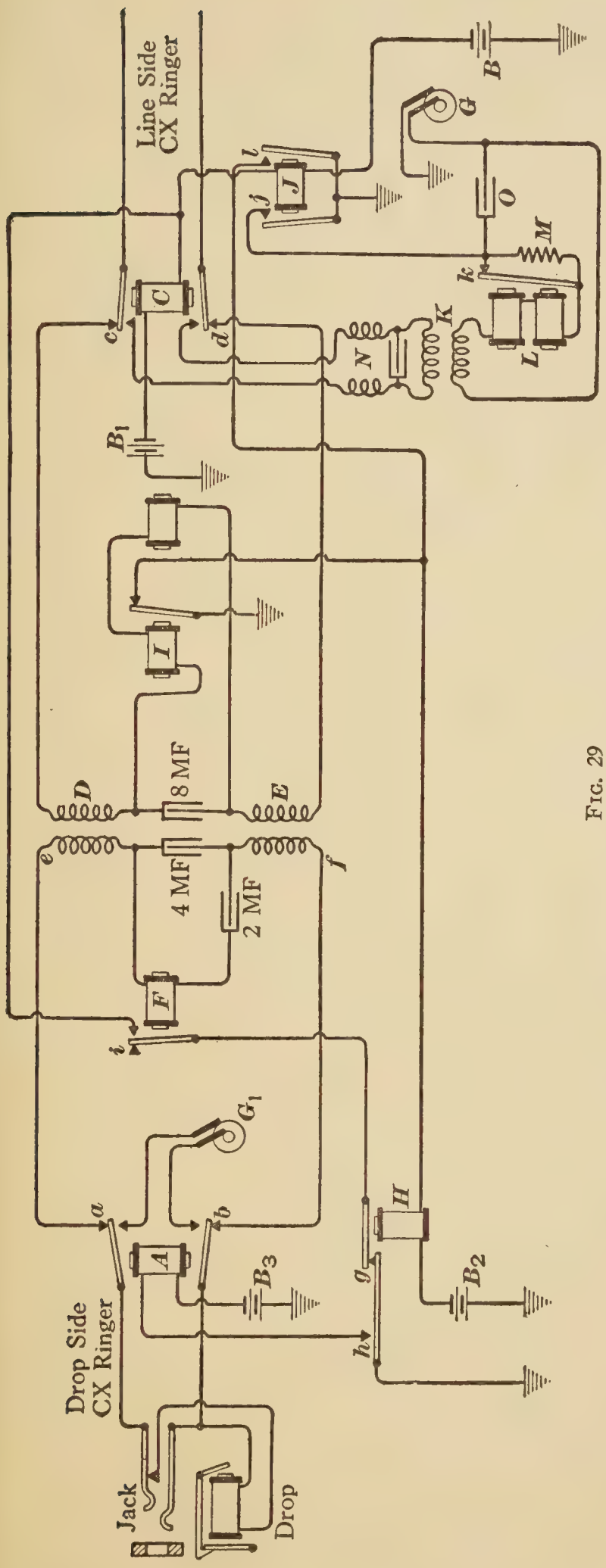

FIG. 29

50. A modification of the preceding composite ringing circuit, used by the Bell Telephone Companies and known as type B is shown in Fig. 29. The telegraph circuits used by this company in connection with composite systems are generally of the polar-bridge duplex type, the operation of which depends on reversals of current for marking and spacing signals. The frequency of these reversals is about twenty cycles per second, and with the circuit arrangement shown in Fig. 28, a current of such a frequency would have a tendency to operate the relay *F* and thus interfere with the operation of the telephone portion of the circuit. The composite ringing circuit of Fig. 29 is so arranged that it will remain practically unaffected by the current reversals in the telegraph circuit. The high-

frequency signaling current passes quite readily through the coils of the high-frequency relay *I*, which operates to open relay *H* and to close relay *A* and thus connects the generator G_1 in circuit with the drop. Locally applied ringing current will operate relay *F*, which completes a circuit from battery B_1, through relay *C*, contact *i*, and the armatures of relay *H* to the ground. The circuit of relay *I* in this case will be open at contacts *c* and *d*. The repeating coil *D E* reduces the effect of Morse impulses in the drop side of the ringer. The 4-microfarad condenser across the terminals of relay *F* acts as a shunt to the undesirable current that may be found in the circuit of relay *F*, and the 2-microfarad condenser reduces further the tendency of this current to pass through the relay.

MORSE BATTERY ON COMPOSITE CIRCUITS

51. Morse battery voltage on composited circuits should be kept as low as possible. Sixty volts at the end of the circuit is as high as is desirable. However, many circuits are in use with as high as 160 volts at each end. If the telegraph service is duplex, it is generally the bridge duplex system. The differential system does not require so high a voltage for operation, but is more likely to have current-wave shapes that will cause induction on parallel circuits, and also interfere with telephone transmission in the same composite circuit. The bridge coils of the bridge duplex system round off the telegraph currents and thus prevent interference in the telephone portion of the circuit.

GROUNDED COMPOSITE CIRCUITS

52. On composite circuits grounds and crosses with other wires may cause the composite ringers to operate and to interrupt conversation. In the case of a ground it may become necessary to discontinue service temporarily on the telegraph branches of the circuits when this condition occurs until the trouble is cleared. A short circuit between the two wires constituting the composite circuit will cross the two Morse branches of the circuit and shut off the telephone communication over the pair

of wires. The telegraph service may be partially continued under this condition by disconnecting service on one of the telegraph branches of the circuit until the short circuit is cleared, thus leaving the other telegraph branch working. The branch that is kept working may be very sluggish because the capacity of the other branch is attached to it through the short circuit, but it will be partially workable.

TELEGRAPHONE, OR GROUNDED COMPOSITE TELEPHONE AND TELEGRAPH SYSTEM

INTRODUCTION

53. A combination of telephone and telegraph apparatus that will permit the simultaneous transmission of both telephone and telegraph messages over a single line wire with a ground return is called a *telegraphone, or a grounded composite telephone and telegraph system.* By the addition of telephone apparatus to a ground-return telegraph line, the usefulness of the line is increased without any additional expense except the cost, installation, and maintenance of the additional telephone apparatus.

Telephones can thus be added to Morse circuits where interruptions in the telegraphic currents are of comparatively low frequency and where the change in potential of the current due to the operation of the telegraphic apparatus is not excessive. Telephones cannot be so satisfactorily operated on duplex or quadruplex lines, and, except under favorable conditions, it is not practicable to use them on lines over which printing telegraph machines are employed. This subject is treated in another Section. The frequency of such telegraph currents may be great enough to render it much more difficult to keep the telegraph currents out of the telephones. On account of the many different conditions, such as size, length, and material of line wires, kind of relays and other apparatus used, no definite statements can be made regarding the number of stations that can be operated on a single line. But the general statement may be made that successful operation should be

practicable over ordinary telegraph lines up to 100 miles in length and with as many as five intermediate telegraph stations. On a short line, the service will be better and more stations can be operated than on a long line having similar equipment. This service is not well suited to the congested territory where power and communication lines will give considerable interference by induction. It is better suited to the prairie country of the west which is sparsely settled and where wires are few. It is found to cause cross-talk into metallic-circuit telephone lines that parallel it, and it is almost impossible to find any preventive means to eliminate this cross-talk.

GROUNDED COMPOSITE CIRCUITS

54. Telegraph Stations.—The arrangement of apparatus on a ground-return line, as devised by the Western Electric Company, for a grounded composite telephone and telegraph circuit, is shown in Fig. 30. Wherever the telephone currents must pass a telegraph station, as at intermediate telegraph stations *C* and *E*, a 1-microfarad condenser *d* is bridged across the telegraph-station apparatus outside of the peg switch so that the high-frequency voice currents and most of the lower frequency telephone signaling currents can readily pass by the telegraph instruments. Thus the impedance of the telegraph relays and the opening and closing of the keys have very little effect upon the telephone currents. To prevent the chattering of the telegraph relays by the part of the telephone signaling currents that does not pass through the condenser, all telegraph relays at intermediate stations on the composited part of the line are bridged with a 1,200-ohm, non-inductive resistance. This resistance should be mounted at some convenient place near the telegraph relay, such as beside it, on the table, under the table, or on the wall. At the terminal telegraph stations *A* and *G*, through which the telephone currents do not have to pass, the condensers and non-inductive resistances are not necessary. At the intermediate station *E*, two telegraph sets are shown looped in the same line circuit. It is assumed that the circuit closer for each key is closed in Figs. 30, 31, and 32.

55. Telephone Stations.—Each telephone set is connected from the line, through a suitable fuse and an open-space cut-out, or arrester, to the ground. Thus the telephone sets are in parallel, that is, bridged between the line and the ground. To allow the telegraph currents to pass by the telephones, there is

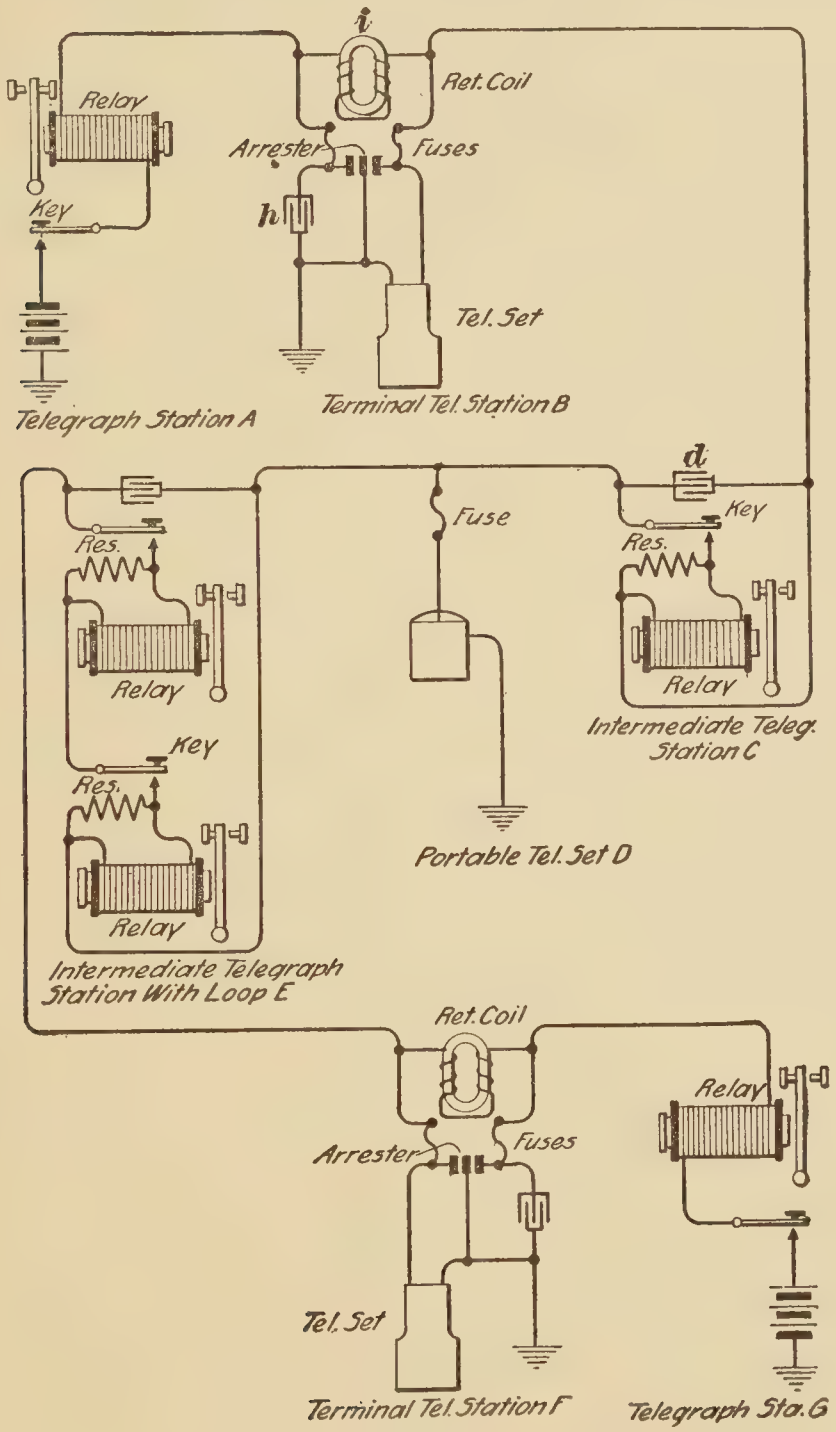

FIG. 30

a 50-ohm impedance, or retardation, coil *i*, Fig. 30, in series with the line at each telephone station. The impedance coil, on account of its high impedance to the high-frequency telephone currents, forces the latter through the telephones to the ground, instead of allowing them to pass to the ground over the tele-

graph line beyond the telephone. But the telegraph current readily passes through these impedance coils on account of their much lower impedance to the much lower frequency telegraph current. To prevent the telegraph current from passing to ground, condensers are connected between the impedance coil and the ground; one of these condensers, which has a capacity of 1-microfarad, is shown at *h*, where it is connected between the ground and the end of the line that is not composited. The other condenser is in the telephone instrument that is connected between the ground and the part of the line that is composited. These condensers also aid in the elimination of disturbing currents that may reach the line from inductive or other causes and to prevent the telegraphic current from producing annoying disturbances in the telephone receivers.

56. Protector.—The open-space cut-out, or arrester, Fig. 30, consists of two copper blocks insulated from each other by a thin strip of mica, which is perforated to form an air gap. One block is connected to the line and the other to the ground. If an arc forms across an arrester and lasts long enough to allow the 7-ampere fuse to melt, the telephone is disconnected from the line without affecting the telegraph circuit, unless its fuses, which are usually of larger capacity, are also melted. Copper blocks do not allow so low a potential to jump across them as do carbon blocks and accordingly should not be used where there is any danger of crosses with high-potential circuits. It is claimed, however, that they are equally effective in guarding against lightning, and unlike carbon blocks give no trouble from carbon particles getting in between the blocks and grounding the line.

57. Telegraph and Terminal Telephone Stations.—In Fig. 31 are shown, in detail, the connections for a station where the telephone circuit ends but beyond which the telegraph line may extend to other telegraph stations. If the telegraph circuit also ends at this station, the uncomposited line *a* is grounded at this peg switch, otherwise it is similarly grounded at some distant station. If this station is the end of the line, the line *b* would be grounded; if it is not the end of the line, the

line *b* would run to a distant telegraph station. At a station having a telephone but no telegraph instrument, no peg switch

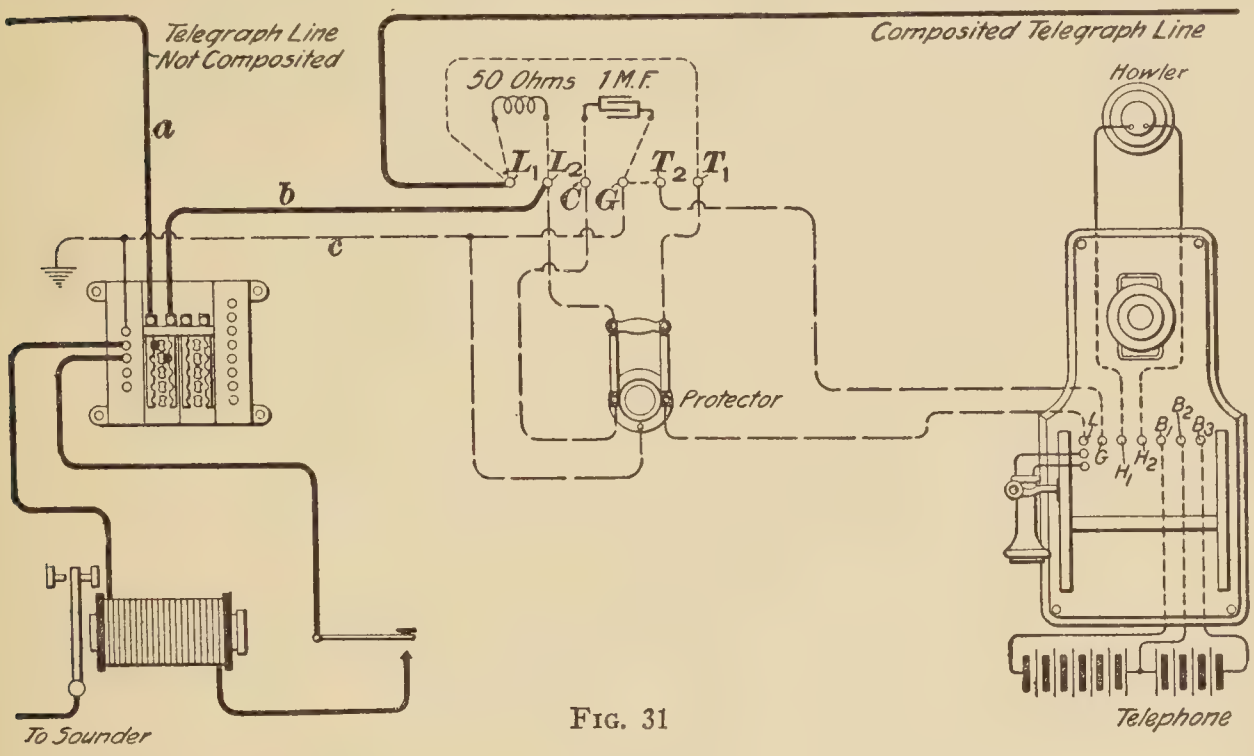

FIG. 31

would be required and the wire *c* would be run direct to the ground. The line terminals are indicated at L_1 and L_2; the condenser and ground terminals at C and G; and the telephone terminals at T_1 and T_2. On the telephone the terminals L and G

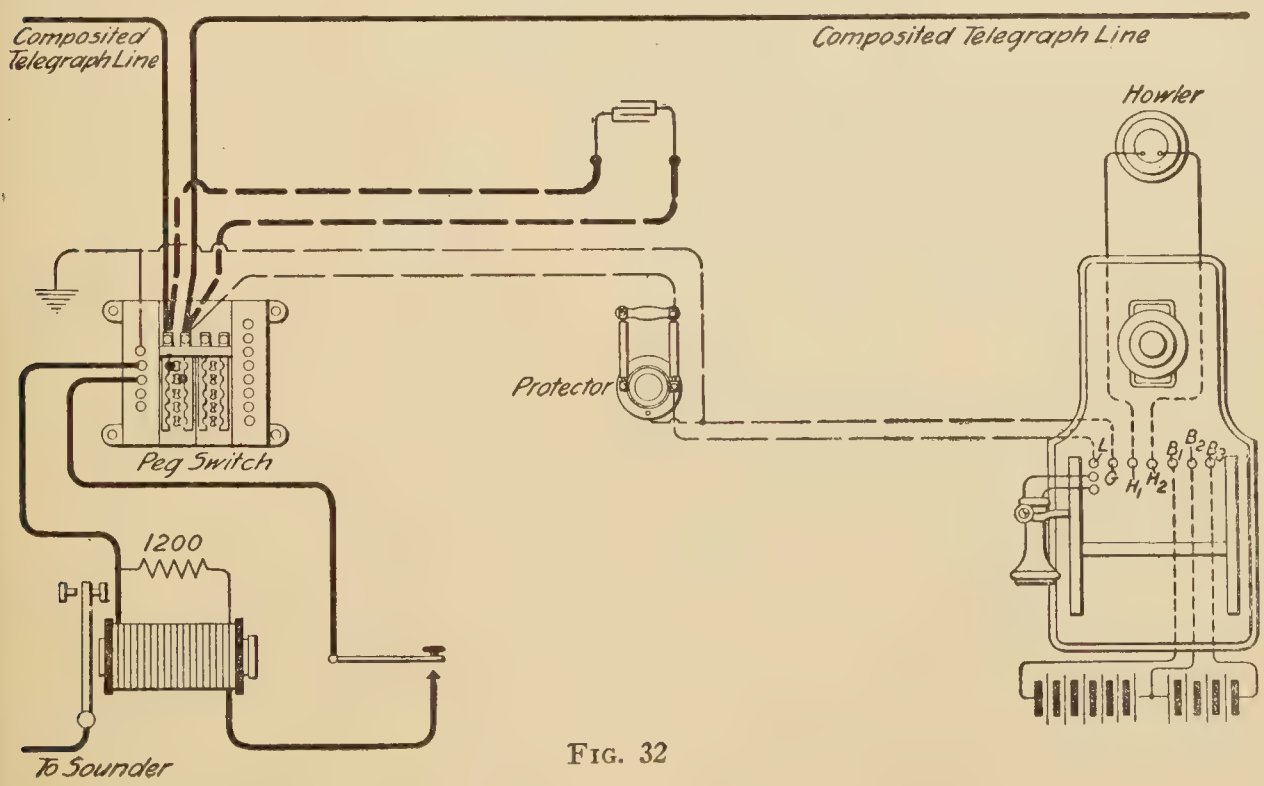

FIG. 32

connect to T_1 and T_2; the terminals H_1 and H_2 to the *Howler*; the terminals B_1, B_2, and B_3 to the battery.

58. Intermediate Telegraph and Telephone Stations.—At an intermediate station where the line does not terminate and where there are both telephone and telegraph sets, the arrangement is as shown in Fig. 32. In this case the line is composited in both directions from the intermediate station. As there is no condenser connected from the line directly to the ground, as shown at *h* in Fig. 30, at an intermediate telegraph and telephone station, only one side of the protector, as indicated in Fig. 32, is used.

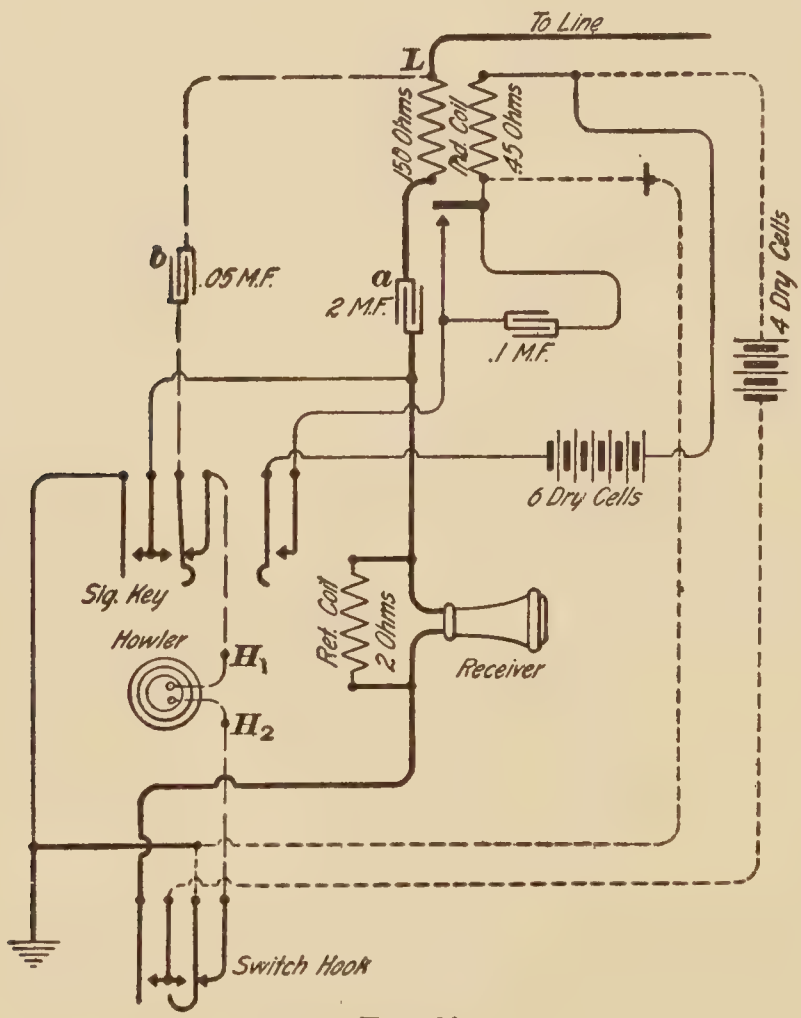

FIG. 33

59. Receiving Signaling Circuit. In Fig. 33 are shown the complete connections of the telephone set used at terminal and intermediate stations on composite line circuits. The battery of four dry cells is used for talking and the battery of six dry cells for signaling. There are the usual switch hook, and a key to be used for signaling a distant telephone. The connections will be easier understood by arranging the devices in three circuits as shown in Fig. 34. Under normal conditions, the apparatus is arranged, as shown in (*a*), to receive signals. The signaling currents must be of higher frequency than would be produced by an ordinary magneto generator in order not to interfere with the telegraph relays, but this high-frequency current will not ring properly the usual polarized telephone bell. Hence, instead of a bell, a device called a *howler* is used to give an audible signal. The howler is a special telephone receiver equipped with a resonating horn and is mounted on a base by

itself, except when placed inside the box of a portable telephone instrument. It may be located in any convenient place where its operation will attract attention and yet be out of reach of persons telephoning, as their handling of it may put it out of order.

60. Adjustment of Howlers.—The sound emitted by the howler can be varied by moving the diaphragm nearer to or farther from the magnets. One method of adjusting the howler is to have the most distant station keep signaling current on the line until the shell containing the diaphragm has

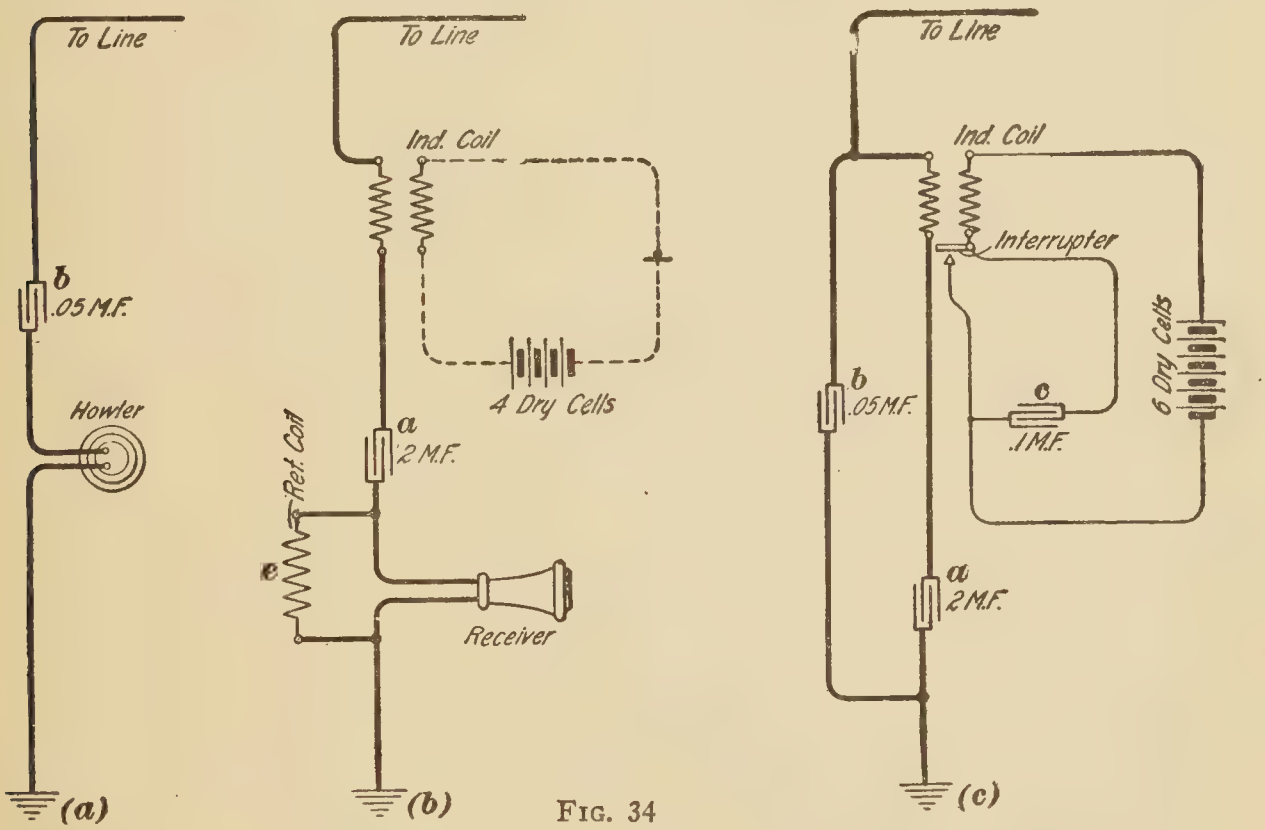

FIG. 34

been adjusted to give the desired tone; the locking ring may then be used to fix the shell firmly in place. As the locking of the metal shell in place tends to move the shell slightly away from the magnet, due allowance should be made in adjusting the howler to guard against thus throwing the howler out of adjustment. Should the magnets in the howler become demagnetized or weakened after being in service a long time, the howler should be replaced by a new one and the defective howler returned to the maker for repairs.

61. Signal-Transmitting Circuit.—In Fig. 34 (*c*) is shown the arrangement when the signaling key is closed. For oper-

ating a distant howler, the six dry cells, the primary of the induction coil and its vibrating contact are connected in series. A 1-microfarad condenser *c* is connected across the vibrating contacts to reduce the sparking and to improve the operation of the device. The vibrator works like the vibrator of an ordinary vibrating bell, or medical induction coil. By its rapid action, it produces in the secondary of the induction coil alternating currents of a frequency and strength suitable for operating the howler at a distant telephone station arranged as shown in Fig. 34 (*a*), and at H_1 and H_2, Fig. 33. The 2-microfarad condenser *a*, Figs. 33 and 34, and the .05-microfarad condenser *b* not only improve the operation of the induction coil but also avoid the forming of a closed path from the line to the ground that would allow the telegraph current to pass to the ground, and thus lessen the amount of telegraph current reaching the distant station.

62. Talking Circuits.—When the signaling key is released and the receiver is off the hook, the talking apparatus is arranged as shown in Fig. 34 (*b*). The transmitter is in a local circuit with four dry cells and the primary of the induction coil. The receiver is shunted by a retardation coil *e*, and both are connected in series with a 2-microfarad condenser *a* and the secondary of the induction coil. The condenser prevents the formation of a closed path from the line to the ground, through which telegraph currents could pass, and assists rather than injuries the quality of the telephone transmission. The retardation coil around the receiver has a movable core that can be adjusted to meet different line conditions. This retardation coil renders the receiver less sensitive, but this seems necessary in order to make it less sensitive to the annoying noises caused by induction and leakage on the line. To make up for this loss in sensitiveness of the receiver, a more powerful primary battery and transmitter than are generally found in ordinary telephone sets are used. Ordinary disturbing currents are largely shunted past the receiver through the retardation coil.

63. Adjustment of Retardation Coil.—If the disturbing noises in the receiver become troublesome, the iron core should

be moved out of the 2-ohm retardation coil *e*, Fig. 34 (*b*), in the station telephone set so as to reduce the impedance of the coil and permit a larger proportion of the current to pass around, instead of through, the receiver. On the other hand, to maintain the volume of sound in the receiver as loud as possible or desirable, the amount of current diverted around the receiver should be as small as is consistent with the necessary freedom from the disturbing noises. The core should be withdrawn, therefore, no further out of the coil than is necessary to secure the desired result.

In the portable telephone set, the iron core of the 2-ohm retardation coil is permanently adjusted, because the disturbing

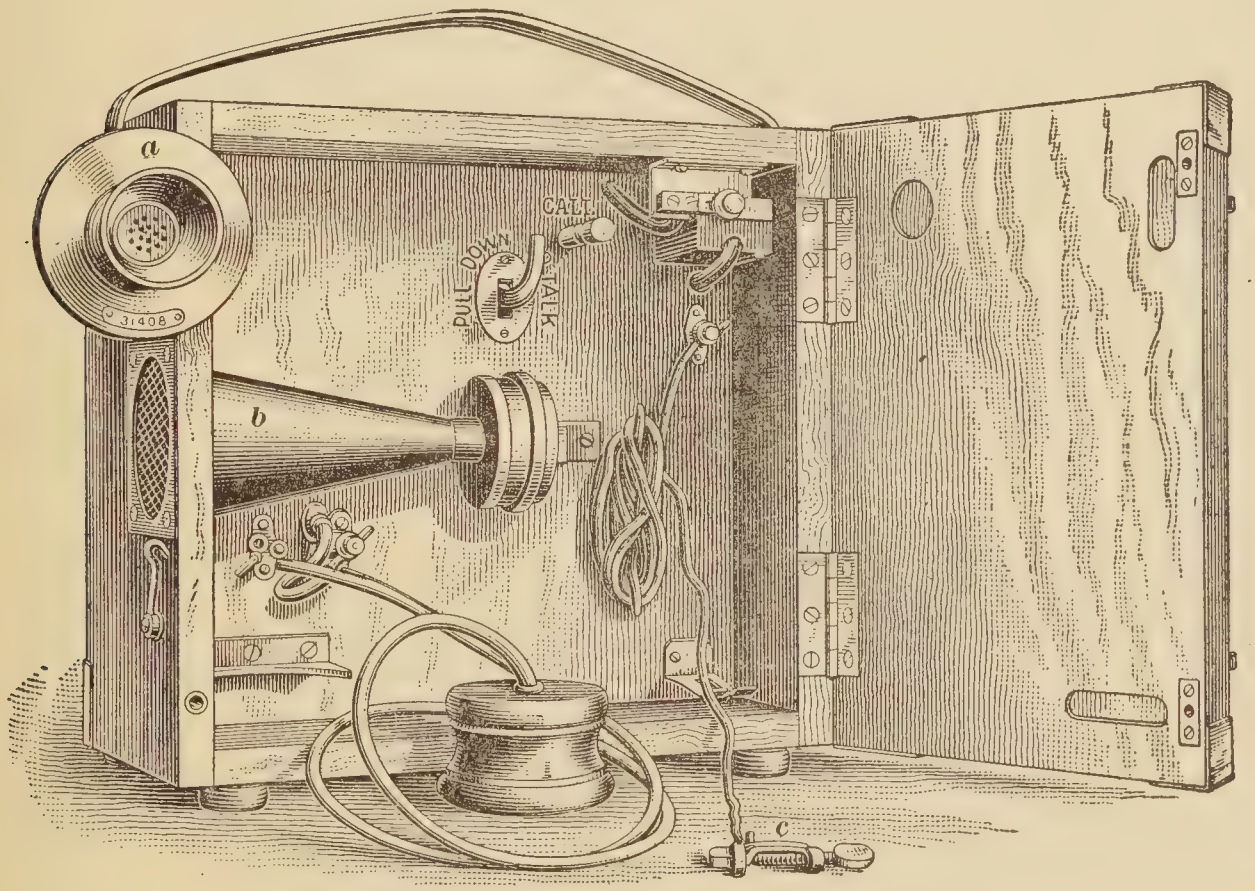

FIG. 35

noises vary at different points along the telegraph line, and, owing to the temporary use of the set, do not warrant readjusting the core every time the set is put in service at a different point.

64. Portable Telephone.—An intermediate telephone station can be established at any point along a grounded composite line by connecting one terminal of a *portable composite tele-*

phone set to the line wire and the other terminal to the ground. Such a portable set with the door open and the transmitter *a* swung out ready for use is shown in Fig. 35. The howler *b* is used instead of a bell. At *c* is shown the clamp for making connection with a rail or any other metallic rod connected to the earth, while the connection with the line wire is made by means of a pole jointed like a jointed fish rod with a suitable hook at the top end and a flexible wire connected to it running down the jointed pole. Behind the board shown in this view are four dry cells, the induction coil, condensers, and necessary switches. The connections for this portable telephone set are shown in Fig. 36. The four dry cells are used for both talking and signaling purposes.

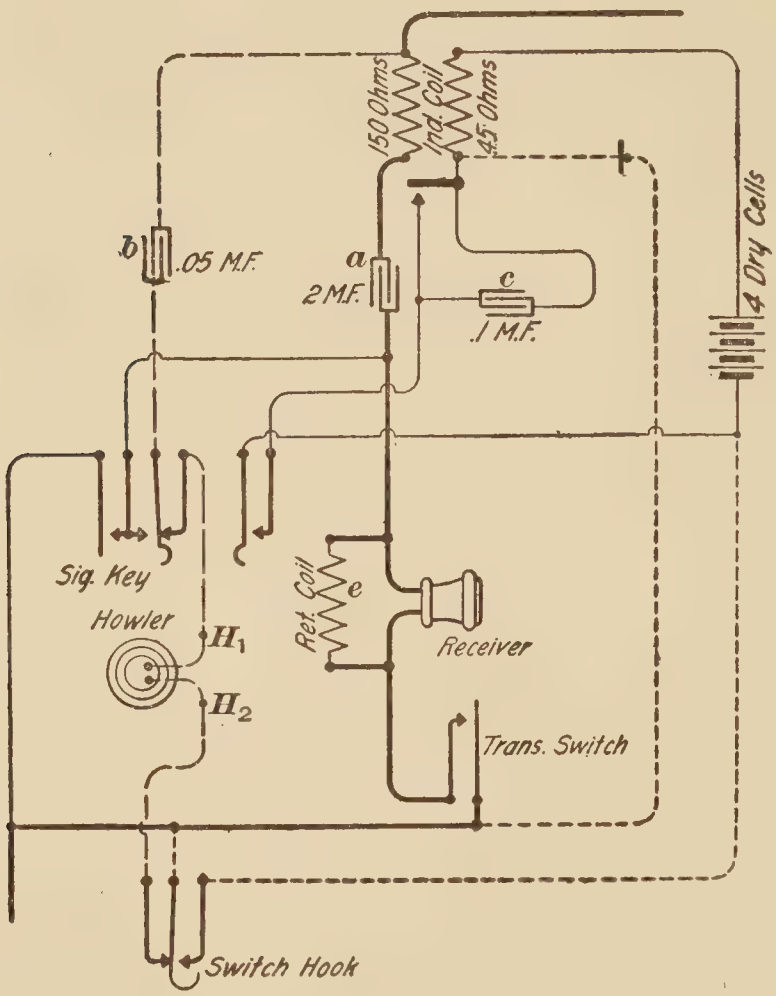

FIG. 36

TROUBLE ON GROUNDED COMPOSITE CIRCUITS

65. Locating Trouble.—When a grounded composite system is not working properly, the trouble may be due to the line being out of order, to a defect in the apparatus or wiring in the telegraph stations, or to a defect in the apparatus or wiring in the telephone stations. Line trouble is cleared by the methods usually employed in all telegraph systems. The information given here for locating trouble in grounded composite circuits applies especially to the Western Electric Company system, but very much of it may be applied to any grounded composite system.

66. Station Troubles.—Trouble at telegraph stations that are equipped with telephone apparatus may be in the telegraph apparatus, the condenser in series with the line at the peg switch and shunting the telegraph apparatus, or in the resistance shunting the telegraph relay. Trouble in the telegraph apparatus should be cleared in the usual way. If the condenser is short-circuited, no telegraph messages can be sent from that station; if the condenser is open, there will be poor telephonic transmission beyond the break. In case the resistance shunting the relay is open, the telephone-signaling currents may cause a chattering of the relay.

Trouble at telephone stations may be traced to a ground across the protector blocks; to a loose or open connection between the telephone set and telegraph line, such as an open fuse; to defects in the apparatus or wiring of the signaling circuit in the set (represented as far as practicable by the light lines in Figs. 33 and 36); to defects in the apparatus or wiring of the listening circuit in the set (represented by the heavy lines in Figs. 33 and 36); or to an open ground connection. Such troubles will not ordinarily interfere with the continued operation of the telegraph apparatus.

67. Signaling Trouble.—When an operator is able to talk satisfactorily over a line but unable to signal other stations, he should ascertain whether the interrupter operates when the signaling key is depressed. If it does not, he should test the battery, and if that is all right, try a different adjustment of the contact screw on the interrupter. If the interrupter operates satisfactorily and it is impossible to signal other stations, it should be ascertained whether signaling current is delivered to the line when the key is depressed. This may be determined by replacing the receiver on the hook and disconnecting the line wire from terminal L, Fig. 33, connecting together the terminals L and H_1, and then pressing the signal key, which should operate the howler at the home station. If the local howler does not then operate, the indication is that the trouble is in the telephone set at that station, and the contacts of the switch hook and of the signaling key should be examined to see that

they make good contact with each other. If they do, the trouble may be due to an exhausted battery, loose connections, broken wires, or an open circuit in the 2-microfarad condenser *a*.

To detect an exhausted cell, a low-reading voltmeter or a battery gauge should be connected across each cell in the battery used for signaling purposes, while the switch hook is in the proper position for talking; then after the signaling key has been closed for 1 minute, the reading should be noted. A dry cell having a voltage less than .7 volt under normal working conditions is exhausted and should be discarded.

Loose connections or broken wires can be found by inspection.

If the howler, which could not previously be operated, can be operated when the 2-microfarad condenser *a* is short-circuited across its terminals, the condenser is probably open. If the howler at the signaling station operates satisfactorily when the line is disconnected from terminal *L*, and terminals *L* and H_1 are connected together and the signaling key closed, the indication is that the trouble is not in the telephone set. However, it may be caused by an arc in the arrester at the signaling station, or by trouble at the receiving station where the howler may be out of adjustment or open, the .05-microfarad condenser *b* may be defective, or there may be an open circuit in the wiring. The removal of the copper blocks in the arrester at the signaling station will, therefore, determine at this stage in the tests whether the trouble is in the distant station.

68. Trouble at Receiving Station.—To test for trouble at the receiving station, the terminal *L*, Fig. 33, should be connected to the howler terminal H_1. If the howler then operates, there is an open circuit in the condenser *b*; if it does not operate, the howler should be tested by itself. To do this, the howler should be connected to one cell from the battery and as the circuit is closed the operator should listen for a click in the howler. If no click is heard, the trouble is in the howler; if heard, there is an open circuit in the wiring outside the howler

69. Transmitting Trouble.—If there is trouble in hearing messages at a distant station while messages are clearly heard at the home station, the speaker should talk more distinctly, with his lips close to the mouthpiece of the transmitter. If the receiving at the distant station is still unsatisfactory, the trouble may be due to an open circuit in the condenser *d,* Fig. 30, at an intermediate telegraph station, or in the primary of the talking circuit at the sending station, or in the receiver or its cord at the receiving station, Fig. 34 (*b*).

Although an open circuit in the condenser *d,* Fig. 30, at an intermediate telegraph station would interfere with the transmission of the voice currents beyond the break, it would not interfere with the voice currents reaching a station on the same side of the break as the sending station. If the trouble is in the primary or the secondary of the talking circuit at the sending station, there will be no trouble in hearing messages at the receiving station transmitted to it from other transmitting stations known to be in good condition. If the difficulty occurs in the secondary, or receiving, circuit at the receiving station, the sending station will have no trouble in making itself heard at other stations known to have a good receiving circuit.

70. Trouble in Talking Circuit.—At the sending station, the talking circuit may be tested by listening to the receiver; if the secondary circuit is not open and there is no defective apparatus in this circuit, the usual low sounds characteristic of aerial lines will be heard. These sounds vary in loudness according to the length of the line and its exposure to other electric circuits, but they are not often loud enough to interfere with telephone transmission. If the secondary circuit is thus determined to be in good condition, the primary circuit may be tested by listening in the receiver while speaking or blowing into the transmitter or gently tapping it. These sounds will be distinctly heard in the receiver if the primary circuit is in good working order, or a click will be heard in the receiver when the switch hook is operated. If such sounds are not heard, the apparatus and wiring in the primary circuit should be examined, and the battery inspected for an open circuit.

A battery test with an ammeter is here recommended. This test is made by connecting the ammeter in the primary circuit, and after the receiver has been off the switch hook for 1 minute, noting the current in the ammeter. If the battery is working perfectly, it should give a current of more than .14 ampere after it has been thus connected for 1 minute. This corresponds to approximately 2.8 volts across the terminals of the talking battery while the latter is under load, that is, furnishing current to the primary circuit.

71. Receiving Trouble.—If the condensers on the line are not defective, and there is no trouble in the talking circuit, the trouble is in all probability in the receiving circuit at the distant station. The inability to hear distinctly, though there is no difficulty in transmitting messages to a distant station, indicates trouble in the secondary of the home set or in the primary of the distant set. This circuit, as shown in Fig. 34 (*b*), consists of the secondary of the induction coil, the 2-microfarad condenser *a*, the receiver in multiple with the 2-ohm retardation coil *e*, the switch hook, and the ground. A thorough inspection should be made of all parts of this circuit for poor connections, and if none are found, an examination should be made of the apparatus in the secondary circuit for defects and poor adjustments.

72. Receiver Defects.—In case trouble in the receiver cannot be remedied by adjusting the core of the retardation coil, the trouble may be in the receiver itself. Trouble in receivers may be caused by dust or dirt settling on the pole faces of the magnet and damping the vibrations of the diaphragm. To clear this trouble, the receiver cap should be unscrewed and the pole faces of the magnet wiped perfectly clean.

Buckled diaphragms are sometimes a cause of trouble in telephone receivers. The buckling is generally caused by pencil points or other sharp objects being pushed against the diaphragm and denting it. When a diaphragm has thus been injured, it should be replaced by a new one. Occasionally, weakened receiver magnets are a source of trouble. If they

are not sufficiently strong to hold the diaphragm to them when the receiver cap is removed and the receiver given a vigorous shaking in the direction of its length, a new receiver is necessary.

73. Bad Receiver Cord.—The receiver cord will in time become worn or possibly injured so as to cause trouble by opening the circuit either intermittently or permanently. As the wire strands within the cord may be broken without the appearance of the cord betraying it, this trouble is difficult to locate without tests. If the wires in the receiver cord are broken so as to open the receiver circuit, or if the winding of the coils in the receiver is open, no sound will be heard in the receiver.

A good method of testing a receiver and its cords for an open circuit, is first to connect the leads from one battery cell directly to the receiver terminals. If the receiver does not give an audible click at the instant this circuit is completed, and the diaphragm is in proper position, it may be safely assumed that the wiring in the receiver is open and will have to be repaired. If the click is heard, the receiver is all right. Then the cords should be tested by connecting them to the receiver and repeating the test, a click in the receiver upon connecting the battery to the cords indicating no break in them, and the absence of the click indicating that there is a break. A worn cord that is breaking the circuit intermittently might not be detected by such a test, but if the cord is bent or shaken while the receiver is held to the ear, a scraping sound will be heard whenever the cord is bent so as to open the circuit.

74. Tests and Remedies for Grounds.—Ground troubles may be due to foreign matter between the copper blocks of the protector, to a defective condenser *a* or *b*, Figs. 33 and 36, in the telephones, to a defective condenser between the line and the ground at a terminal telephone station, or to a cross between the primary and secondary parts of the talking circuit. To determine if the trouble is in the protector, remove the metal cap and pull out both of the copper protector blocks. If this clears the ground, the blocks should be cleaned and

replaced, and if necessary, new micas should be used in place of the old ones. Under no circumstances should cardboard or paper be substituted for the mica.

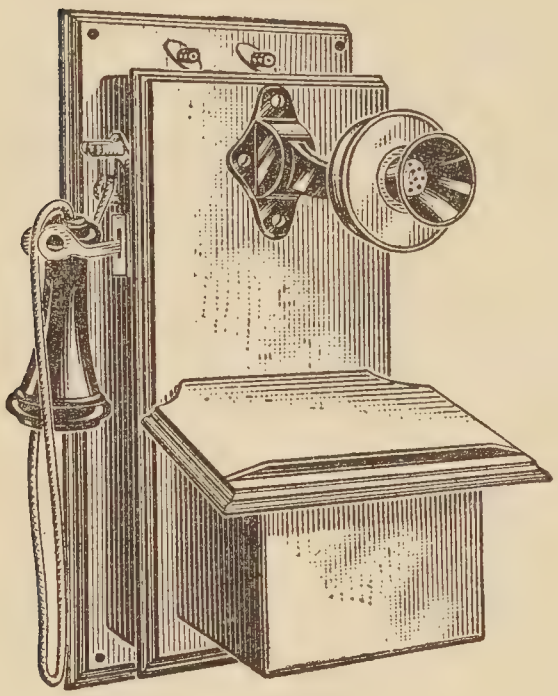

Fig. 37

If the trouble is not in the protector, and the separation of the line wire from the protector or telephone set clears the ground, the condensers and wiring in the telephone set should be tested. If the trouble is noticeable only when the receiver is on the hook, the condenser *b*, Fig. 33, should be investigated. If, however, the ground occurs only when the receiver is off the hook, the condenser *a* is probably causing the trouble. In case either condenser *a* or *b*, Figs. 33 and 36, is found defective, any available condenser that will clear the trouble temporarily may be inserted between the telegraph line and the telephone set until the defective condenser is replaced. If no suitable condenser is at hand, the telephone should be disconnected from the line until repairs can be made.

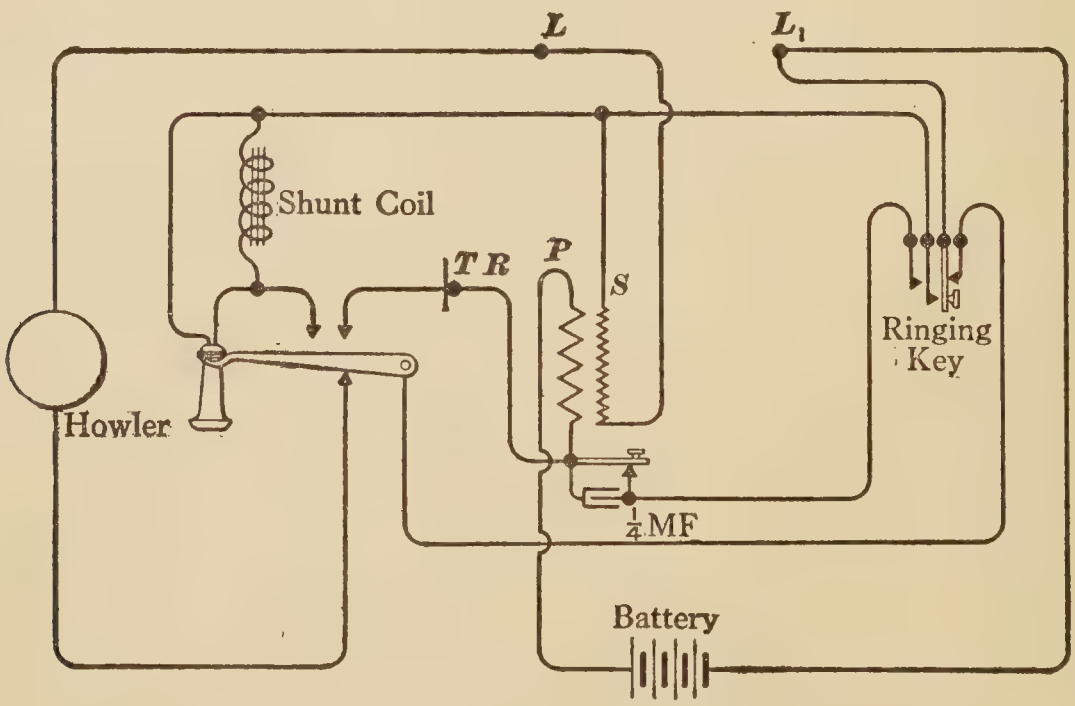

Fig. 38

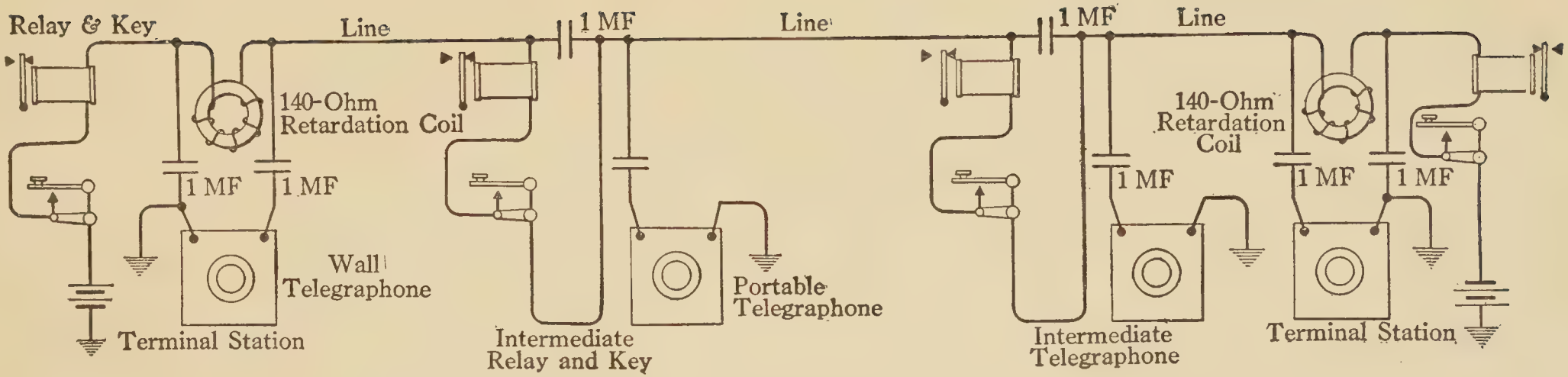
Relay & Key
Line
1 MF
Line
1 MF
Line
140-Ohm
Retardation Coil
1 MF
1 MF
Wall
Telegraphone
Terminal Station
Intermediate
Relay and Key
Portable
Telegraphone
Intermediate
Telegraphone
140-Ohm
Retardation
Coil
1 MF
1 MF
1 MF
Terminal Station

FIG. 39

In a terminal station, as at station *B*, Fig. 30, a ground may occur due to a short circuit in the 1-microfarad condenser *h*, between the line and the ground. To determine whether this is the trouble, disconnect the ground wire; if the trouble then ceases, it indicates that the condenser is defective. To clear the trouble temporarily, disconnect this condenser from the ground. In doing this, however, the ground connection of the telephone set, which is usually made at this point, must not be disturbed, as this would leave the telephone out of service.

TELEGRAPHONE SYSTEM OF THE RAILWAY TELEPHONE MANUFACTURING COMPANY

75. The Railway Telephone Manufacturing Company's system, formerly known as the Sandwich system, is in very extensive use in the United States, Mexico, Cuba, and Central and South America. In theory it is similar to the Western Electric Company system. It uses but one battery both for signaling and talking. The wall set is shown in Fig. 37, and the wiring in Fig. 38. In this set the howler is mounted inside of the set with a hole in the wood box directly in front of the diaphragm. A tin horn is used to amplify the sound of the howler. The horn is enclosed in the box underneath the shelf, Fig. 37.

76. The retardation coils, shown in Fig. 39, have a resistance of 140 ohms each. The terminal telegraphones connect from line to ground through 1-microfarad condensers. Intermediate telegraphones can either be bridged across the line and ground through a 1-microfarad condenser as shown in the figure, or they may be connected across the relays through a 1-microfarad condenser; in the latter case the telegraphone is in series with the line. Portable telegraphones are used with line poles and grounding rods. The 1-microfarad condenser is included with and forms a part of each portable telegraphone set. In place of portable telegraphones some railroads install regular wall sets in the caboose and baggage cars from which connection is made permanently to the trucks of the cars for the ground connection, and a line pole is used for making the connection to the line wire.

SIMULTANEOUS TELEPHONY AND TELEGRAPHY

(PART 2)

Serial 2103B Edition 1

PHANTOM TELEPHONE SYSTEMS

GROUNDED PHANTOM SYSTEMS

DEFINITION OF TERMS

1. An arrangement of apparatus whereby two telephone conversations may be held over the same pair of wires at the same time is termed a *grounded phantom telephone system.* An arrangement of apparatus whereby three telephone conversations may be held simultaneously over two pairs of line wires is termed a *metallic phantom telephone system.* The operation of both the grounded and the metallic phantom systems depends on similar principles. In the grounded phantom telephone system the circuits are arranged in about the same manner as in simplex telephone and telegraph systems, telephone instruments being, however, substituted for the telegraph apparatus.

The operation of both the grounded and the metallic phantom telephone systems is based on the principle of the Wheatstone bridge and the same explanation will apply as in the case of simultaneous telephone and telegraph systems. Phantom systems may also include an arrangement for the simultaneous transmission of telegraph messages, in which case the arrangement is usually referred to as a *composited phantom system.*

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IMPEDANCE-COIL GROUNDED PHANTOM

2. One method of providing an additional telephone circuit in connection with an existing metallic telephone circuit is shown in Fig. 1. The usual telephone circuit indicated in the figure consists of the telephone set *A*, line *1*, line *2*, jack *Ja*, and drop *Da*. Briefly stated, the operation of the metallic telephone circuit is as follows: Turning the crank of the megneto generator at set *A* sets up an alternating current in the metallic circuit including the winding of the drop *Da*. The operation of the drop gives a visual signal to the operator at the switchboard, informing him definitely of the line that

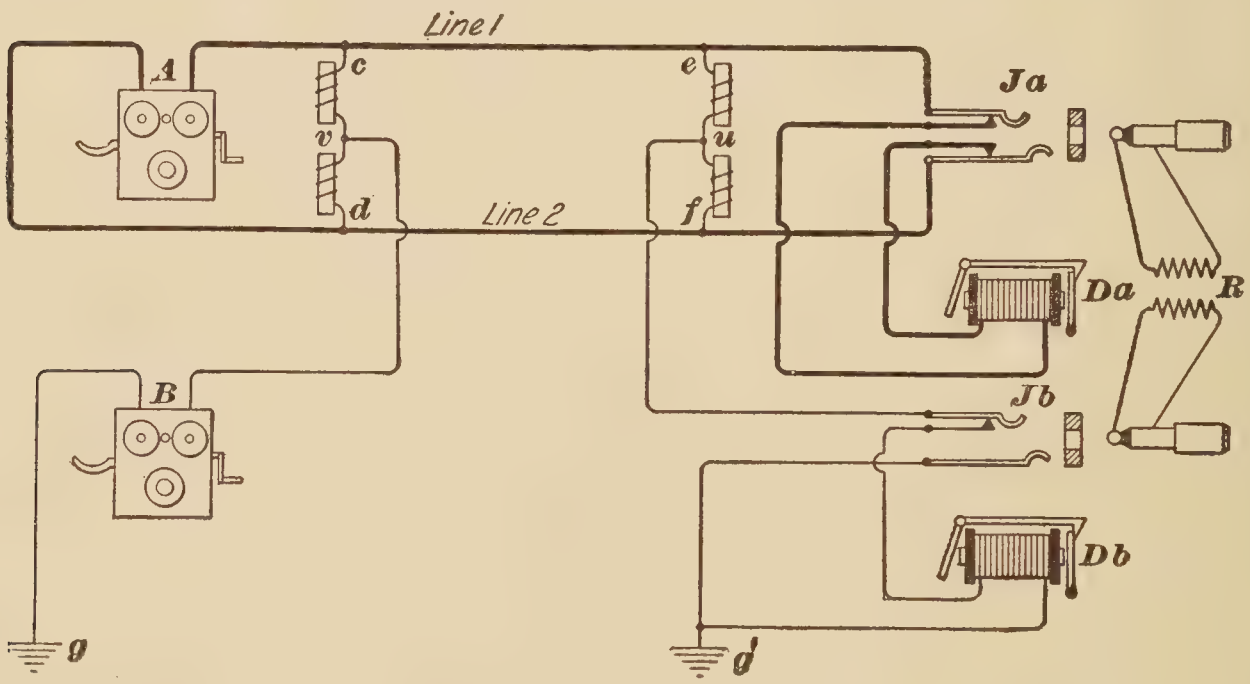

FIG. 1

desires a further connection. The jack *Ja* is of the cut-off type; that is, when a plug is inserted into the jack, the outside springs of the jack are separated from the inside springs, thus cutting off the connection to the drop and completing a circuit through the cord circuit, not shown in the figure.

3. For the phantom circuit, two impedance coils are provided, one at each end of the line. Each impedance coil has two windings wound on the same iron core. The coil has a middle tap and two end terminals. At the telephone-set end the impedance coil *c d*, Fig. 1, is connected across the line, and at the central-office end the impedance coil *e f* is connected

across the line. It should be noted that the impedance of these coils is so high as to prevent almost entirely the telephone and ringing currents originating in the metallic circuit from passing through them. The phantom circuit is then connected to middle points *u* and *v*. The circuit of the phantom circuit may be considered to begin at the ground connection *g*, and continue through the telephone set *B*, point *v*, windings *v c* and *v d* in parallel, line *1* and line *2* in parallel, windings *e* and *f* in parallel, point *u*, jack *J b*, drop *D b*, to the ground *g'*. The impedance of the coils *c d* and *e f* is considerably reduced when connected in parallel, hence the opposition offered by these coils to alternating currents originating in the phantom circuit will be less than the opposition to similar currents in the metallic circuit, owing to the fact that the current in the metallic circuit would have to pass through the windings of the coils in series.

As has been explained in connection with simplex telephone and telegraph circuits, the two line wires of the metallic circuit are in parallel as far as the imposed phantom circuit is concerned, hence no difference of potential exists between the points to which coils *c d* and *e f* are connected. The currents in the metallic circuit and in the phantom circuit will not conflict with each other, and under well-balanced conditions no interference will exist.

4. The interconnection between stations on the metallic and on the phantom circuits should be made through a repeating coil as shown at *R*, Fig. 1. Each impedance coil should have a complete iron circuit and enough turns to give it a very high inductance. For this purpose 600- or 1,000-ohm impedance coils may be used. The longer the line, that is, the greater its resistance, the greater should be the inductance of the impedance coils. The additional circuit is called a phantom circuit because it is an extra circuit obtained without the actual addition of any more line wires than were already in use for the circuit containing the telephone *A*.

REPEATING-COIL GROUNDED PHANTOM

5. Instead of using impedance coils for constructing a phantom circuit in connection with an existing metallic circuit, repeating coils may be used to equal or better advantage. This condition is illustrated in Fig. 2. The repeating coils *c d* and *e f*, here take the place of the impedance coils previously shown. The ground is used as a return for the phantom circuit containing the telephone set *B*.

In the metallic telephone circuit, current variations produced in the primary of the repeating coil induce an electromotive force in the secondary coil, which sets up a current in the secondary circuit. The primary of any repeating coil may be

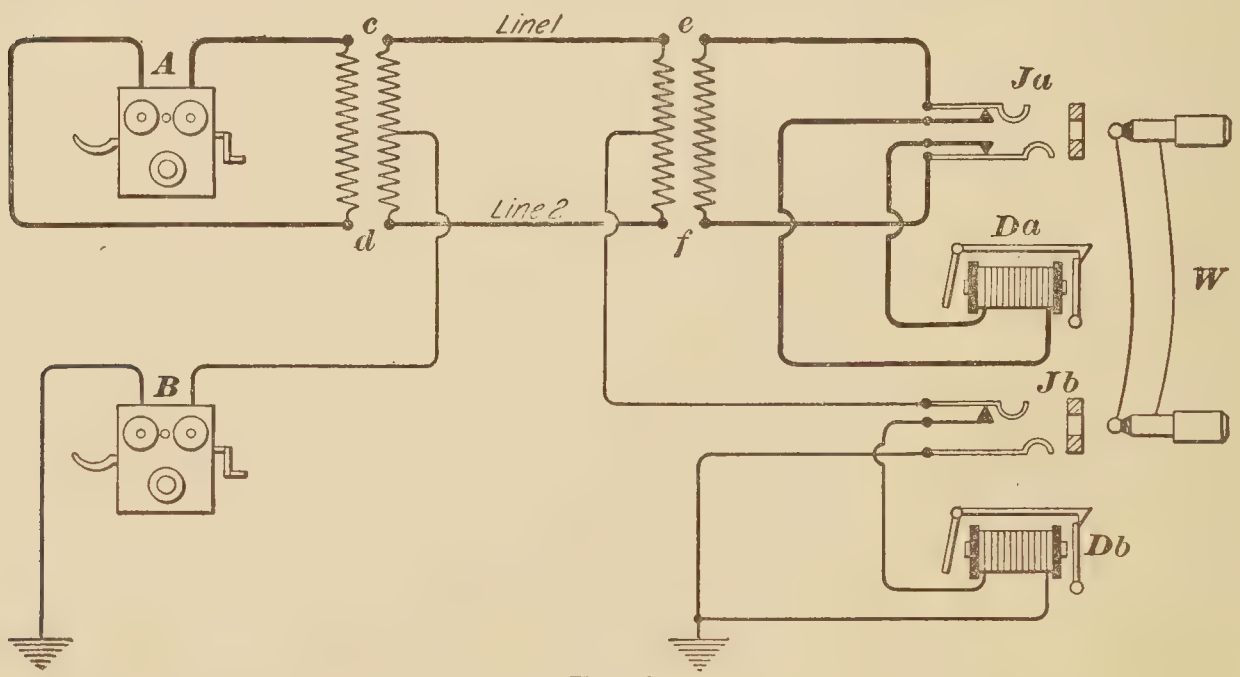

FIG. 2

considered the one through which current passes and sets up a varying magnetic field. The secondary is the coil in which an electromotive force is induced. In the phantom telephone circuit, the connection from the telephone and jack is made to the center of the line windings of the repeating coils. Equal currents pass through each half of the winding, hence the magnetic effect set up by one half of the coil is neutralized by the other half. No disturbance is, therefore, produced by the phantom circuit on the metallic circuit.

6. In the metallic circuit, current variations or alternations produced in the circuit containing the telephone set *A*,

Fig. 2, and the instrument side of the winding of the repeating coil *c d*, induce an alternating voltage in the line winding of the repeating coil. The current set up by this voltage passes through the line and also through the line winding of the repeating coil *e f*. An electromotive force is, therefore, induced in the winding of the repeating coil *e f* on the switchboard side, which, in the case of signaling current, operates the drop *D a*, and talking current passes through the jack *J a* and the cord-circuit equipment at the office.

The phantom path if traced from the ground at station *B* may be said to continue through the line wires in parallel with the instrument connections extending from the center points of the line windings of the repeating coils through jack *J b*, and drop *D b* to the ground. The connection between the metallic and the phantom circuits may in this system be made conductively, as indicated at *W*; that is, no repeating coil need be used in the cord circuit.

The instruction governing the operation of grounded telephones applied also to grounded phantom systems, and unless there is comparative freedom from inductive disturbances it is not practical to use the grounded circuit. Furthermore, grounded circuits are no longer considered good practice and should not be adopted without a complete investigation or trial test.

METALLIC PHANTOM SYSTEMS

IMPEDANCE-COIL METALLIC PHANTOM

7. An objection to all phantom circuits using the ground as a part of one circuit is the difficulty of preventing in the grounded line undesirable noises due to induction from other circuits, such as telephone, telegraph, and power lines. For this reason it is usually more satisfactory to arrange two complete metallic circuits, as shown in Fig. 3, so as to obtain three telephone circuits.

The four lines terminating in jacks J_1 and J_2, J_3 and J_4 constitute two distinct telephone circuits. The third circuit,

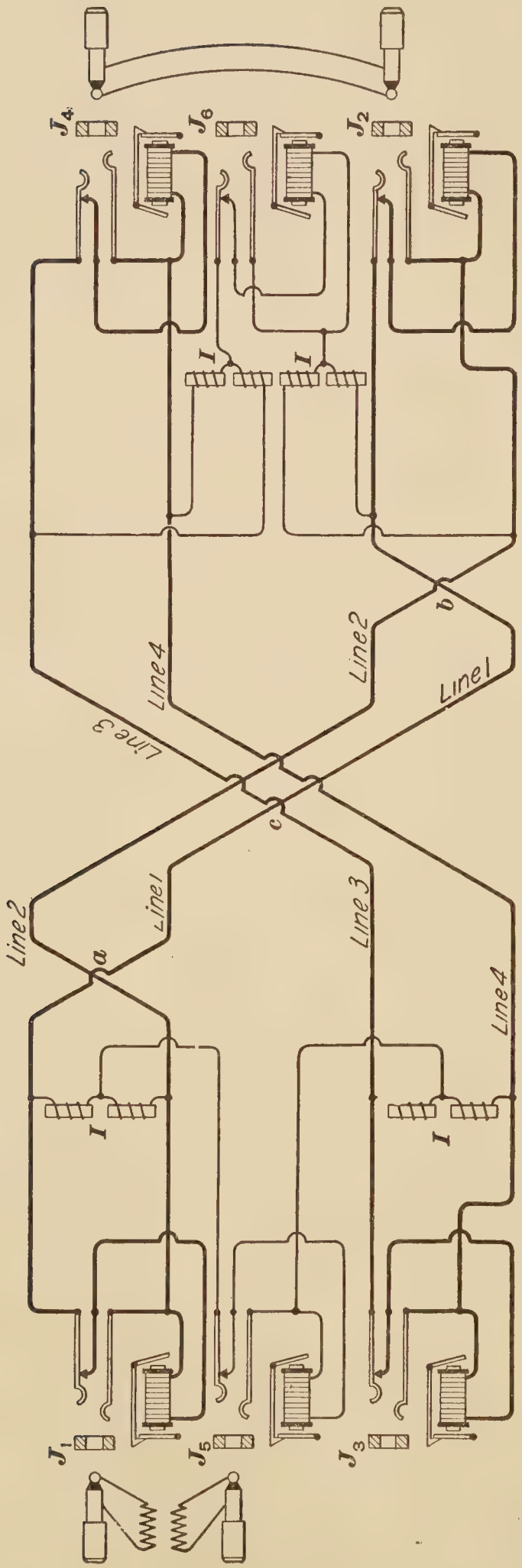

FIG. 3

which terminates in jacks J_5 and J_6, is the phantom circuit. As in the impedance-coil grounded phantom system, connection is made to the physical lines by means of impedance coils *I*. Here, however, each side of the phantom circuit is connected to a separate telephone circuit, the two sides of each physical circuit constituting one side of the phantom circuit.

8. To eliminate cross-talk between the two pairs, the line wires constituting the metallic circuits should be transposed, as indicated at *a* and *b*, Fig. 3, the same as any two pairs of parallel and adjacent telephone line wires. Furthermore, one pair of wires should be transposed with respect to the other pair, as shown at *c*, in order to eliminate cross-talk between the phantom circuit and any other circuit that may be parallel and adjacent but not associated with this circuit. Standard

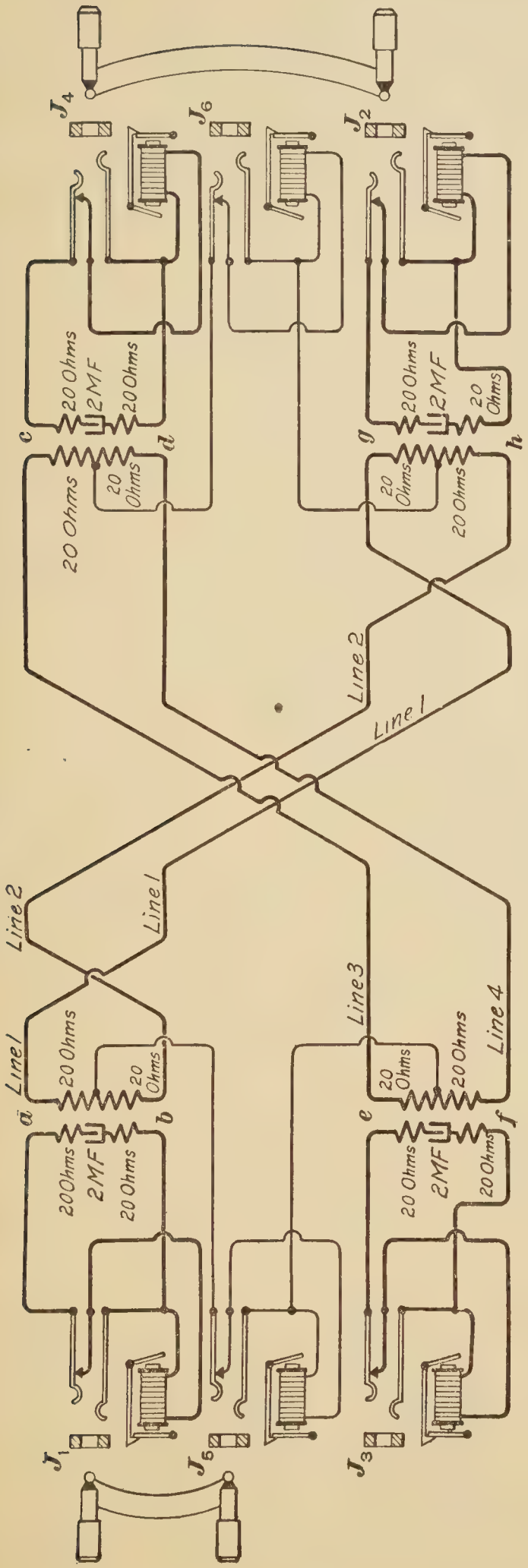

FIG. 4

systems of transpositions are available for such use.

To avoid cross-talk and other disturbances, both halves of each impedance coil should have equal resistance and equal impedance to voice currents; the impedance of the two halves should not differ by over $\frac{1}{2}$ per cent. Each complete impedance coil should consist of four windings so connected as to form two coils of equal resistance and the same number of turns. It is common practice to use standard repeating coils for the impedance coils, leaving two of the four windings unconnected.

REPEATING-COIL METALLIC PHANTOM

9. With the arrangement shown in Fig. 4, three telephone circuits may be obtained over two pairs of line wires. The phantom circuit is here imposed on the two physical circuits by means of repeating coils

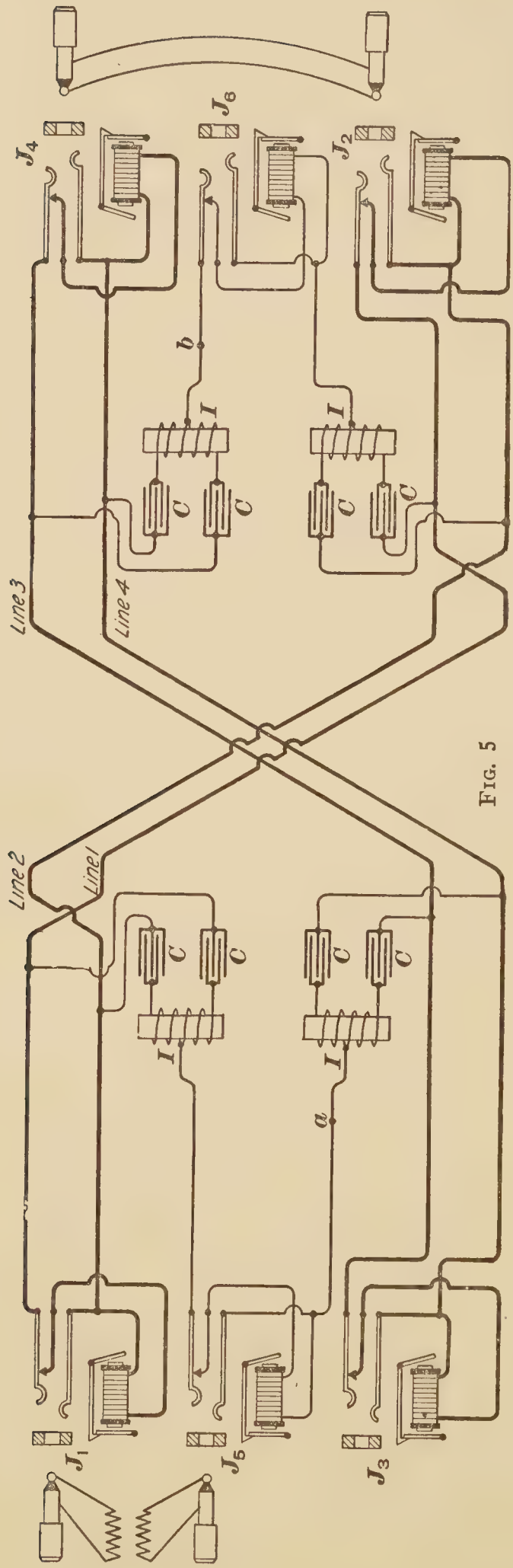

FIG. 5

ab, *cd*, *ef*, and *gh*. The 2-microfarad condenser connected in the middle of each of the repeating coils, on the drop side, is omitted, unless the cord circuits are common-battery supervisory-signal type, in which case the condenser is necessary to prevent the operation of the supervisory signals by the current in the path through the repeating coil. This phantom telephone system resembles so closely the simplex telephone and telegraph system using repeating coils that no further comment seems necessary.

CONDENSER PHANTOM

10. Condensers *C* may be used with impedance coils *I*, as shown in Fig. 5, for obtaining three telephone circuits from two pairs of line wires. It is common practice to use standard repeating coils, such as the Western Electric Company's 47-A coil for an impedance coil *I*. In this case only two windings of the repeating coil are used, the other two being disconnected. Each of the used coils is connected as shown

at *I*, Fig. 5, in which the extreme terminals are connected to the condensers and the intermediate point between the two coils on the one side to the tip of the phantom jack and on the other side to the ring of the phantom jack. Each of the condensers *C* shown in the figure should have a capacity of about 2 microfarads; the capacity of these condensers should also be accurately balanced in pairs. In some cases they are tested and paired up by the manufacturer.

Should the ground be substituted for one of the metallic circuits two telephone circuits with one pair of line wires and the ground will be obtained. Thus, to make use of line wires *1* and *2* only, disconnect the wire leading from the ring of jack J_5 to the impedance coil *I* and ground this jack at point *a*, and also disconnect the wire leading from the tip of jack J_6 to the impedance coil *I* and ground this jack at point *b*. The arrangement is somewhat similar to that shown in Fig. 1.

The condenser and coil arrangement, Fig. 5, is used to a great extent in railroad telephone service on train-dispatching and message telephone pairs. The condensers prevent the coils interfering with or short-circuiting the telephone-selector current impulses used in train dispatching.

COMPOSITED PHANTOMS

11. The various phantom systems just described included no telegraph service. Such service, however, may be imposed upon any of the systems and is very frequently used by companies that have phantom circuits in operation.

Two metallic telephone circuits with phantom telephone and composited telegraph service imposed upon them are shown in Fig. 6. The repeating coil method of phantom imposition is shown in the illustration, although the impedance-coil method could be used just as well. The principle governing the operation of telegraph systems on active telephone lines has already been explained, and since this system is a combination of phantom and composited operation, no new principles are involved.

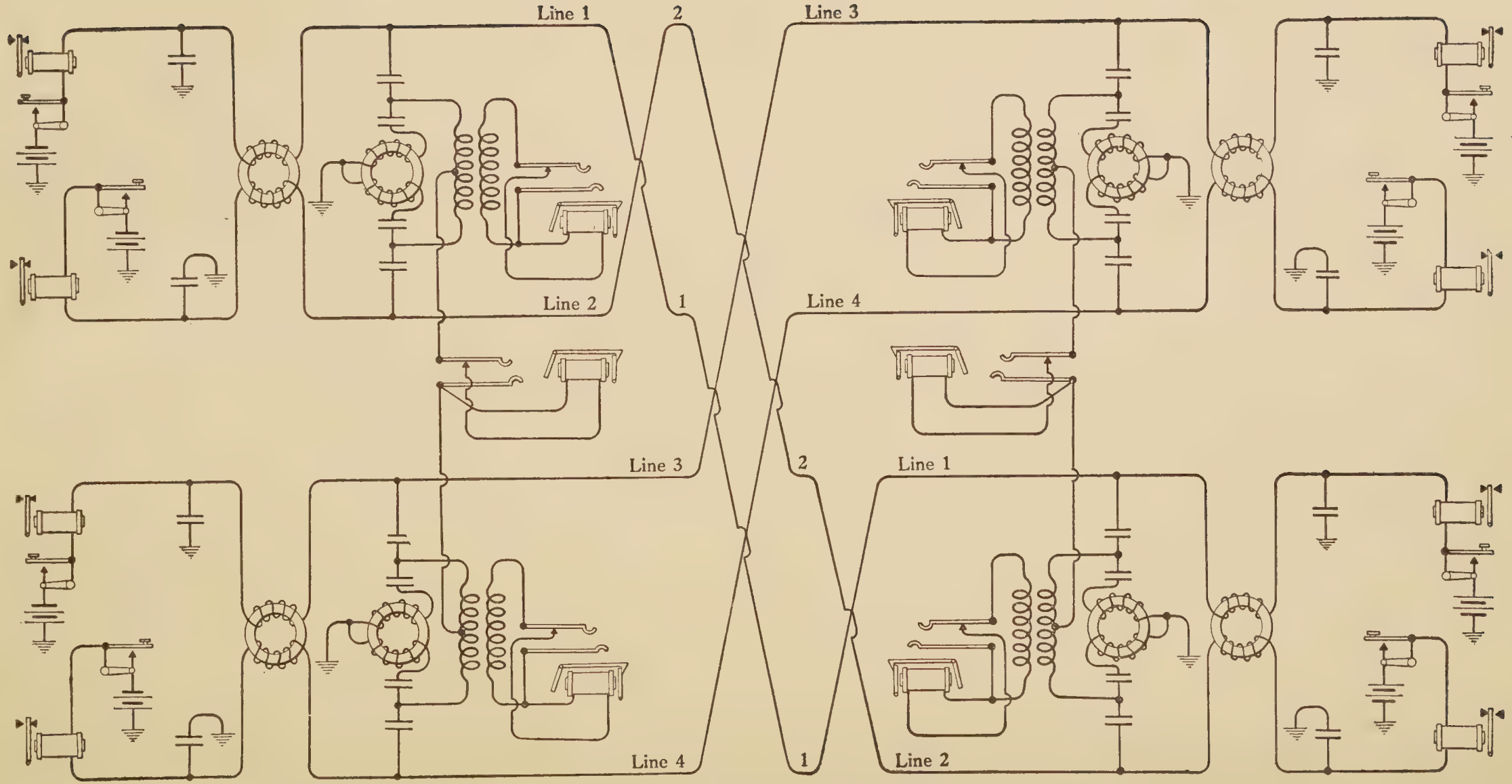

FIG. 6

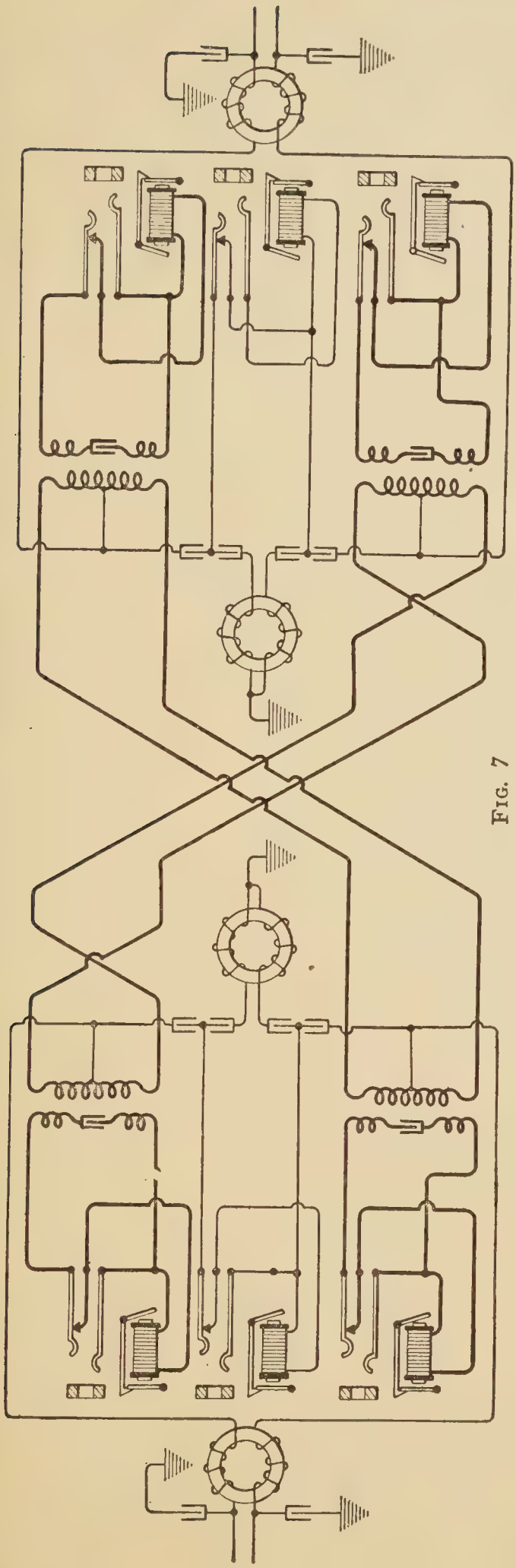

FIG. 7

By imposing a phantom on two composited telephone circuits, the metallic circuits are utilized to their full capacity. When the telegraph service on such circuits is duplex, eleven different communications may be carried over the two pairs of wires without mutual interference.

12. As has been shown, telegraph service may be imposed upon each of the four physical conductors of a phantom circuit. Where only two telegraph circuits are desired on a phantom line, the phantom line itself may be composited, as shown in Fig. 7. This method gives two telegraph circuits, two physical telephone circuits, and one phantom telephone circuit. The telegraph service is simplex in relation to the two physical telephone circuits; that is, the two sides of the telephone circuit form one conductor for the telegraph. When, however, the service is considered from the standpoint of the phantom circuit, it is composite, as each of the sides of the phantom cir-

cuit has additional telegraph service available. This system is also a combination of phantom and composited systems, and both these systems have already been explained.

The choice between the physical sides composited and phantomed as in Fig. 6 and the more simple composited phantom as in Fig. 7, will depend on several factors. When the physical sides are composited as in Fig. 6, there will be greater loss to telephone transmission; this loss is very great on long-haul circuits where several such lines are connected through. If the lines are short and transmission volume abundant, it may be found that the gain in value of two additional telegraph circuits will far outweigh the loss of transmission in obtaining them.

TROUBLES ON PHANTOM CIRCUITS

13. The two wires composing a pair used in a phantom system must be of equal resistance, inductance, and capacity to give a quiet telephone circuit. Generally, the inductance and capacity will be sufficiently equal to cause no trouble if the resistances are equal. If one side of a line should have a loose connection, the resistance of the wire containing the joint may be increased enough to cause cross-talk between the telephone circuits on a phantom telephone system and to cause the telegraph click to be heard in the telephone circuit on a composited phantom system. A partial or a total ground will produce the same trouble.

Short circuits between the two wires constituting a pair on a composited phantom interfere only with the telephone transmission over that pair; they do not injuriously affect the transmission over the phantom circuit. Short circuits on the wires constituting pairs in a phantom made of two composites will interfere with the telegraph service, also with the telephone transmission over the crossed pair, but the phantom circuit itself will not be affected.

Phantom circuits should be provided with lightning arresters at all instruments and terminals to prevent, as much as possible, the tendency of lightning to damage the impedance coils, repeating coils, or condensers on its way to the ground.

To avoid cross-talk with other metallic lines, the two pairs used in a phantom circuit must be transposed, as shown in Figs. 3, 4, 5, 6, and 7, in addition to the regular transpositions between the two wires of each pair as provided in standard phantom transposition plans.

If the metallic circuits used in duplex or simplex systems are kept in good condition, there will be no more trouble on such systems than with two regular independent circuits.

CORD CIRCUITS

14. Where a pair of wires forming a metallic circuit phantomed by means of impedance coils is connected through an exchange with a grounded circuit, a repeating coil should be used in the cord circuit, otherwise the system will act as if grounded on one side. No repeating coil is necessary, however, in connecting a grounded circuit to the grounded portion of a phantom circuit.

In some cases where phantom circuits are obtained by the use of impedance coils, as in Fig. 1, a cord circuit containing a repeating coil is employed to connect a telephone on a phantom circuit with a telephone on the metallic circuit from which that particular phantom circuit is derived. Consider that the two tips of the plugs shown in Fig. 1 are connected together and the two rings are also connected, then the half, for example winding *e u*, of the impedance coil *e f* that is connected to line *1* of the metallic circuit will be short-circuited through the two tip contacts. The other side of the same metallic circuit, for example, line wire *2*, will be connected directly to the ground, through the ring contacts of the two jacks. In such a case, the sound heard in one telephone due to talking in the other would be due mostly to a large amount of cross-talk caused by a badly unbalanced circuit.

15. Cords containing repeating coils as shown at the left, Fig. 5, should also be used to connect a telephone on a phantom circuit, obtained by means of condensers, to a telephone across either of the metallic circuits. To connect the circuits

terminating in jacks *Ja* and *Jb*, Fig. 2, and jacks J_2 and J_4, Fig. 3, a cord circuit without a repeating coil may be used. Generally, repeating coils should not be inserted in cord circuits, Figs. 2 and 4, used in phantom systems obtained by means of repeating coils.

In standard telephone practice, the phantom is chiefly used in toll or long-distance line service, in which case it is not necessary or usual to connect together two lines that extend in the same direction, and hence it seldom occurs that a phantom is connected to one of the physical sides that help form it. Toll cord circuits, therefore, usually do not have a repeating coil for the purpose described, but connect one toll jack direct to another for through connections or calls.

COMPOSITED PHANTOM TELEPHONE CIRCUITS

SYSTEMS AVAILABLE

16. The telegraph systems used on telephone circuits that are composited may be single-line Morse, duplex Morse, quadruplex Morse, or certain types of printing telegraph systems. The single-line Morse is the ordinary method of transmitting a single message over a line wire. The duplex Morse is a system whereby two messages, one in each direction, may be transmitted simultaneously over the same wire. In the quadruplex system, four messages, two in each direction, may be transmitted over one line wire simultaneously. In the printing telegraph system, a combination of positive and negative impulses is sent over the line for every character and function of the printer. The line wire in this system may be operated either simplex, duplex, or multiplex. With the multiplex system, as many as eight printer messages may be transmitted simultaneously over the line wire.

17. The multiplex printer and the quadruplex system are seldom operated on composited telephone circuits. The frequency of the current transmitted in these systems resembles

closely that in the telephone circuit, hence the telegraph would interfere considerably with the proper operation of the telephone. The quadruplex system, aside from its rapid variations of current on the line, has the disadvantage that considerable attention is required to keep it properly adjusted. It also requires a higher voltage for operation than is desirable on composited circuits.

18. The telegraph service on composited telephone circuits has, therefore, its limitations. For best operating conditions, the telegraph service is restricted to the simplex and duplex Morse systems. The duplex Morse system can be used as a two-way, or double, duplex, in which the duplex is operated to its full capacity; four operators are required in this system, one sending and one receiving at each end of each wire. When traffic is light, only one operator is needed at each end of the wire, in which case the one operator alternately transmits and receives telegraph messages.

The duplex apparatus may be connected to single-operated Morse wires by means of half-repeater sets. The operator on the single wire does not know, as far as his methods of using the instrument are concerned, whether it is a single or a duplex circuit. This arrangement of apparatus gives the benefits of duplex circuits as to wide margin under varying weather conditions, together with flexibility of single lines for loops to subscribers

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DUPLEX TELEGRAPH ON COMPOSITE SYSTEMS

19. Advantages of Bridge Duplex System.—Of the three duplex systems, the differential, polar, and bridge, which have been fully explained in other Sections, the bridge duplex system is best adapted for composited service. In the bridge duplex system, impedance coils are used to round off the Morse waves and reduce thereby their tendency to be heard in the telephone circuit as well as in adjacent circuits; this feature is wanting in the other two duplex systems. Ordinarily the bridging duplex requires a higher voltage for the same margin of operation than do the other duplex systems, but owing to the

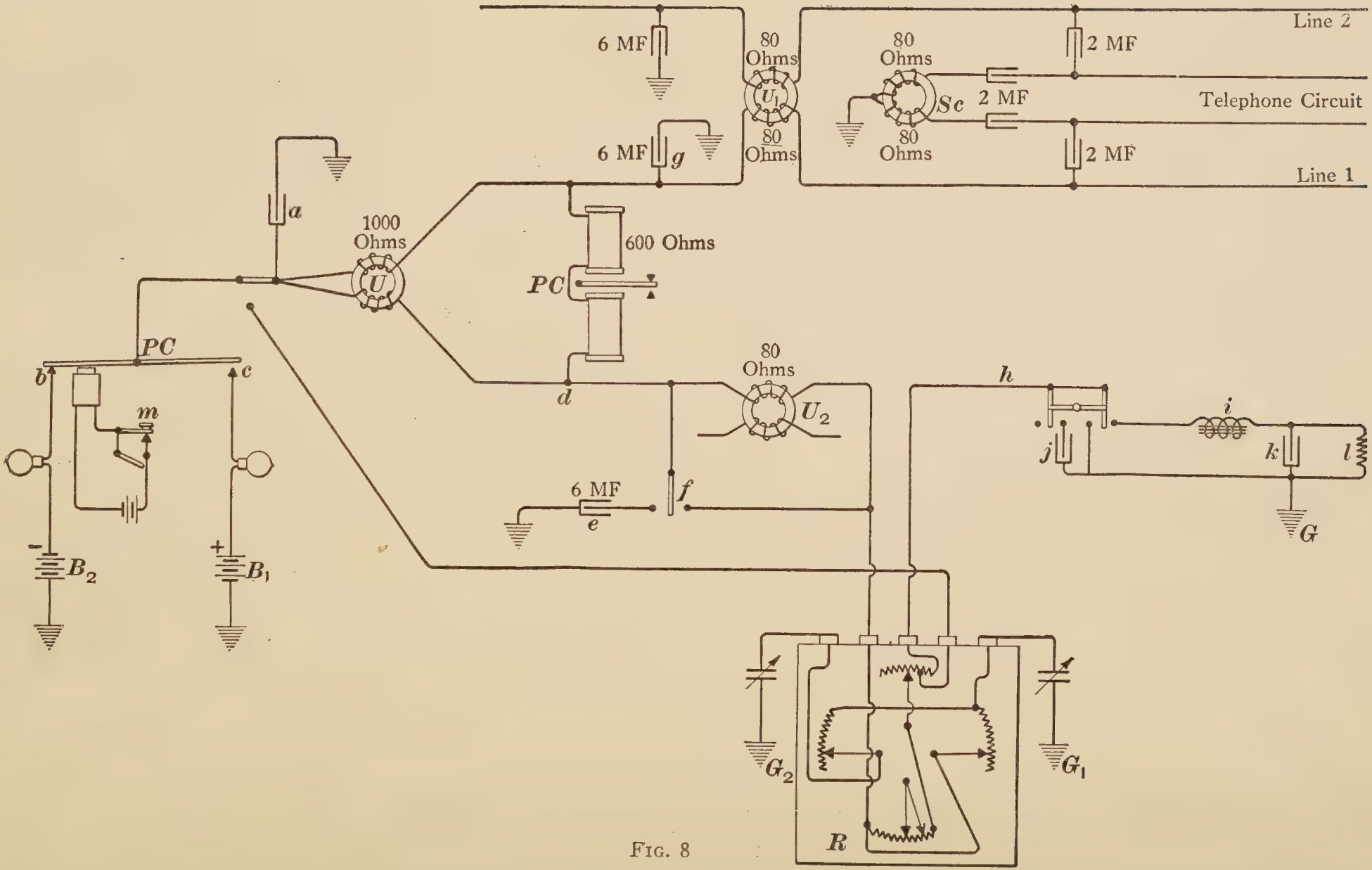
6 MF
80 Ohms
U_1
80 Ohms
Line 2
80 Ohms
2 MF
Sc
2 MF
Telephone Circuit
80 Ohms
2 MF
Line 1
6 MF
g
a
1000 Ohms
U
600 Ohms
PC
PC
b
c
m
d
80 Ohms
U_2
h
i
j
k
l
6 MF
e
f
G
B_2
B_1
G_2
G_1
R

FIG. 8

high impedance of the terminal apparatus the bridge duplex will cause about one-half the Morse disturbance in the telephone of a composited circuit with equal line voltage.

20. Method of Duplexing.—One of the best arrangements for duplexing a composited wire is shown in Fig. 8, in which both sides of the composite set have been included in order to make the arrangement clearer. Line *2* may be duplexed in the same manner as line *1*. The retardation coil *U* has a resistance of 1,000 ohms and the polar relay *P R* a resistance of 600 ohms. The coil *U* is inductively wound so as to force to the ground, through the small condenser *a*, the sharp edges of the telegraph current, leaving a smoother current to pass through the portion of the circuit that is also used for telephoning. This is necessary to avoid the production of telegraph clicks or noises in the telephones. The condenser *a* also reduces the sparking at the contact points *b* and *c* of the telegraph pole changer *P C*.

21. Artificial Line.—The circuit from *d*, Fig. 8, through the various coils and condensers to the grounds *G*, G_1, and G_2 constitutes the artificial line. The more nearly the resistance, capacity, and inductance of this artificial line are equal to the resistance, capacity, and inductance in the real line, and the more nearly they are arranged, or distributed, in the same manner, the better can the duplex telegraph set be balanced and the better will it work. The coil U_1 is inserted to counteract the inductive kick from the corresponding coil U_2, which occurs when the pole changer is being rapidly operated. The retardation coil *S c* assists in preventing the telegraph currents from interfering with the operation of the telephone circuit. The other resistances and condensers are adjusted to balance the line wire itself under various weather conditions. At *R* is shown a form of resistance box regularly used by some telegraph companies.

The condenser *e*, when connected to the cricuit by switch *f*, balances the discharge of the condenser *g*. The switch *f* may be used to cut out condenser *e* and short-circuit the coil U_2. Instead of connecting the wire *h* directly to ground, as is usually done in regular telegraph duplex systems, it is frequently

necessary to balance the coils and condensers in the line circuit at the distant station, by the use of additional inductance at i and capacity at j and k. This is usually more necessary on short lines free of cable conductors, where the capacity of the line is insufficient to counteract the inductive kicks from the coils. If extra condenser capacity is required and inserted at j and k, it is necessary to connect a non-inductive resistance l of from 100 to 500 ohms around one condenser k.

22. Operation.—The sending telegraph operator uses the key m, Fig. 8, to send the message, thereby controlling the pole changer. The polar relay $P\,R$ controls a local circuit containing a battery and a sounder from which another operator reads the incoming message. The equipment at the distant station is exactly the same as shown in this figure.

With the transmitting keys m, Fig. 8, open, the positive poles of similar voltage batteries B_1 and B_3, Fig. 9 (a), are connected to corresponding points a and a_1 at the west and east stations. The directions of the currents in the various parts of the circuit under these conditions are as indicated in Fig. 9 (a). There is no current in the line wire $l\ l_1$. The relays $P\,R$ and $P\,R_1$ are so polarized that they keep their local circuits open when the direction of current through them is from l to j and from l_1 to j_1.

If the transmitting key at the western station is closed, the battery B_2 will be substituted for battery B_1, the polarity applied to point a will be reversed, and the directions of the currents in the various parts of the circuit will be as shown in Fig. 9 (b). The balance of the line and artificial line is such that the operation of the home key does not change the direction or the amount of current in the home relay $P\,R$; hence, the relay does not move its armature. However, the direction of the current in the distant relay $P\,R_1$ has been reversed; hence, it will close its local circuit.

When the distant eastern station closes its key, the relay $P\,R$ will move its armature to the closed contact. If both transmitting keys are closed, the negative poles of similar voltage batteries B_2 and B_4 will be connected to points

a and a_1, and the directions of the currents in the various parts of the circuit are shown in Fig. 9 (c). The currents through the relays $P\,R$ and $P\,R_1$ are in the opposite direction to that shown in (a), and in the proper direction, therefore, to cause

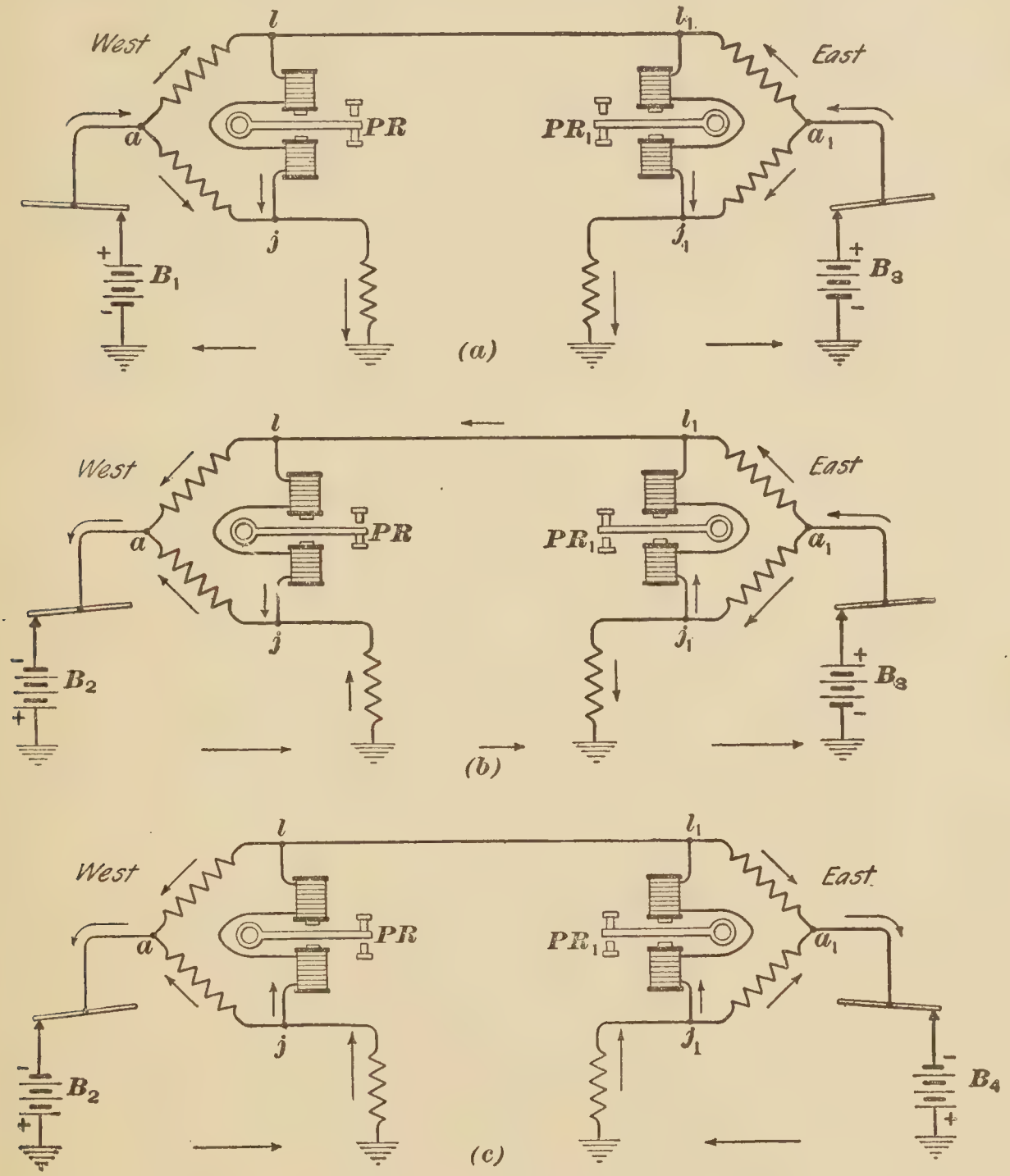

FIG. 9

both relays to close their local circuits. Hence, the key at one end controls only the relay at the other end; consequently, messages may be sent simultaneously by the two sending operators at the two end stations and received by two other receiving operators at the same two end stations.

DUPLEX-TELEGRAPH DIFFICULTIES IN COMPOSITED SYSTEM

23. It would seem a simple matter to duplex one side of a composited circuit; but in practice, a very disagreeable kick is experienced in the polar relay when the transmitting key is operated. It has been found that if the artificial line is made as nearly as possible like the main line in capacity, inductance, and resistance, this kick almost entirely disappears. This effect is obtained by adjusting the artificial-line resistance and the condensers so that minimum kick is experienced in the polar relay when the pole changer at the same end of the circuit is operated. A milliammeter with zero at midscale is now used in series with the polar relay to assist in detecting and eliminating the kick.

24. The general service on a duplex system operated on a composited telephone circuit is hardly equal to the duplex service obtained over a straight Morse line wire, that is, on a wire which is used only for Morse telegraph purposes. In the duplex composite arrangement the circuit has the added inductance and capacity of the composite sets, which increases the length of time required for the rise and fall of a telegraph current impulse. As a consequence, the duplex service on a composited telephone system is not as fast as that on a straight wire. This results, in practice, that duplexes on composited systems require that more repeater stations be installed for a given length of line than in systems where telephone service is not used. However, excellent results are obtained on composited circuits when the lengths between repeaters are not excessive.

EFFECTS OF COMPOSITING OR SIMPLEXING CIRCUITS

25. The introduction of retardation coils and condensers in composited circuits has but little detrimental effect on telephonic transmission, but the Morse circuits suffer considerably. An operator accustomed to working a single Morse system on a wire, if changed to a side of a composite, is very apt to complain at once of the wire being sticky and slow. The

margin or range of adjustment becomes much smaller and it is necessary to *pull up* much higher, that is, move the relay cores back or increase the tension of the retractile spring, or do both, in order to receive the Morse signals from the distant office; but although the circuit seems slow, it will readily transmit messages sent at ordinary speed. Sometimes several of these composited circuits are connected together through repeaters for a long line, in which case the wire will be slow and hard to keep in good working order or, as it is termed by telegrapy operators, *lined up;* the margin, or variation in current strength, will be so small that repeater stations will have difficulty in adjusting.

Sometimes a long cable loop between the exchange and a telegraph subscriber's office is looped to a composite wire; in this case, the subscriber will usually complain of poor service. The capacity of the long loop added to the capacity of the open wire and the composite sets makes an impedance equal to a very long line. In wet weather, the lack of margin becomes very noticeable. A composite on a phantom is handicapped by having the two wires of each pair as one Morse wire with double capacity and leakage, but with only one-half the resistance of one wire. It has the same resistance, capacity, and leakage as a simplex but has the added disadvantage of the composite coils and condensers.

26. Simplex circuits act much the same as composited ones, but the slowness may be taken as due more to leakage and to line capacity. In damp weather, these circuits become very heavy (hard to work) owing to the fact that there are two wires to pick up leaks instead of one. The simplex system has an advantage in having two wires in parallel, with resulting resistance but one-half that of one of the wires, but has the disadvantage of double capacity and leakage.

27. Mr. F. F. Fowle states that one terminal set of standard Bell composite apparatus impairs transmission to the same extent as the introduction of approximately 1.25 miles of No. 19 B. & S. cable conductor, or 35.6 miles of bare overhead No. 8 B. W. G. copper wire. The effect of two terminal sets

will be equal to 71.2 miles of No. 8 B. W. G. Therefore, it is economy to composite only long trunk lines without intermediate telephone or telegraph stations.

The simplex system is somewhat more flexible, but does not present the same economy of line as the composite. The repeating-coil method is employed when grounded ringing telephone generators must be connected to the line, which would otherwise ground the telegraph circuit and cause the relays to chatter. The effect of a repeating coil of the most efficient type introduced into the line at the terminal is equivalent to the introduction of $\frac{1}{3}$ mile of No. 19 B. & S. gauge cable conductor, or 9.3 miles of bare overhead No. 8 B. W. G. copper wire. The effect of an impedance-coil simplex set may be considered as equivalent to .25 mile of cable.

LONG LOADED PHANTOM TELEGRAPH AND TELEPHONE CIRCUITS

28. The commercial success of the New York-Denver telephone and telegraph circuit, put into service in 1911 by the American Telephone and Telegraph Company, depended to a considerable extent on its use for simultaneous telephone and telegraph transmissions. An almost inconceivable number of combinations for telegraph and telephone circuits could be secured by various arrangements of the apparatus. One interesting arrangement giving through telegraph and telephone transmission at the same time is shown in Fig. 10. There were two pairs of line wires between Denver and Omaha, one pair between Omaha and Chicago, two pairs between Chicago and Buffalo, and two pairs between Buffalo and New York. There were full duplex telegraph systems between Denver and Ohama, Denver and New York, and Chicago and New York. For ordering the desired telephone or telegraph connections, one-half of a duplex set was used between Denver, Omaha, and New York, and one-half of a duplex set between Chicago and New York. There was also a simple telegraph circuit between Denver, North Platte, and Omaha for ordering connections. These circuits were termed *order wires*.

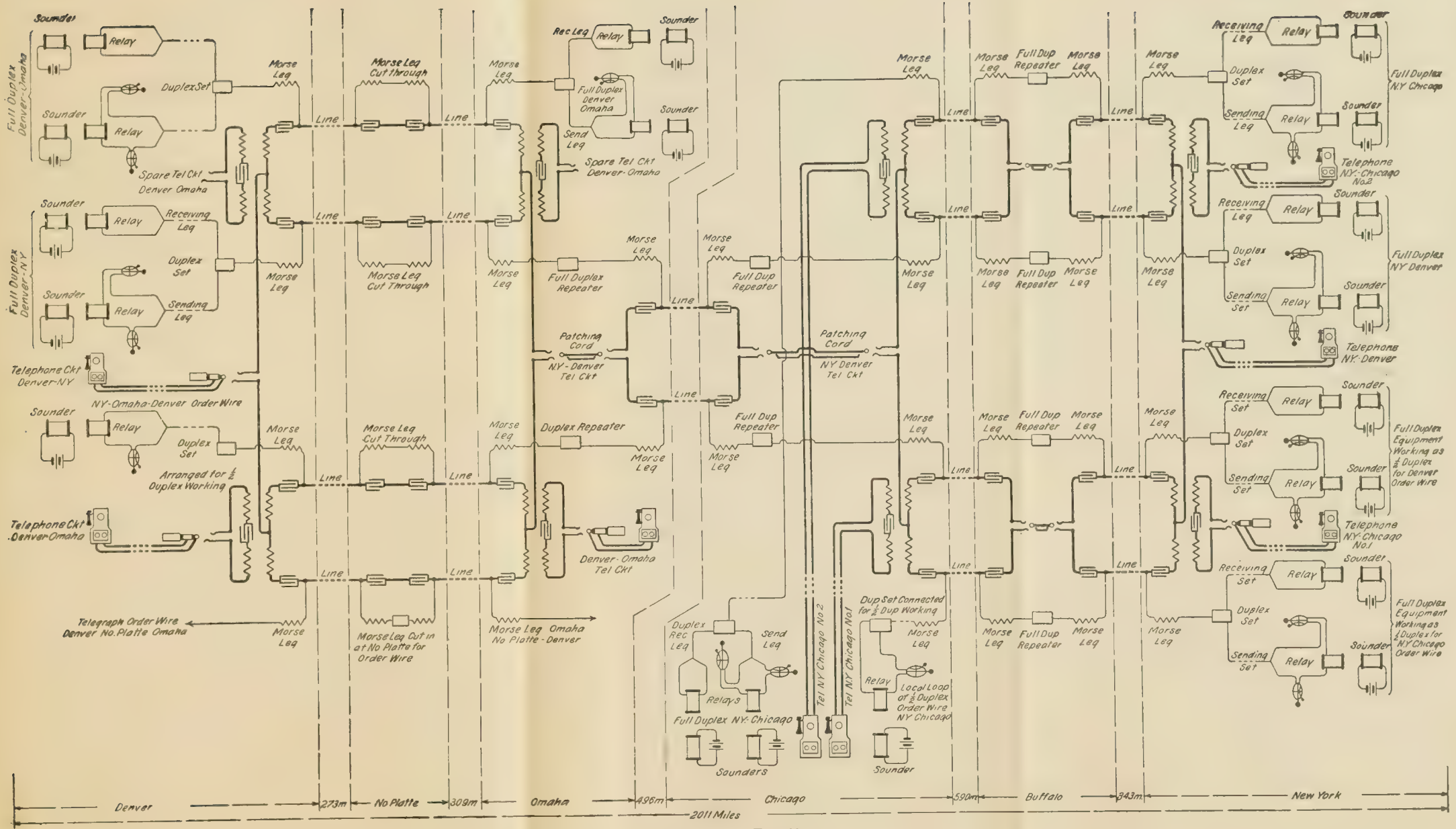

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FIG. 10

Duplex telegraph repeaters were used at Buffalo, Chicago, and Omaha. There was one telephone circuit between Denver and New York, and another between Denver and Omaha, and two between Chicago and New York. The telegraph circuits were arranged on the composite system. To eliminate cross-talk and all other induction disturbances, both the physical and phantom circuits were properly transposed, and to balance properly capacity with inductance, both the physical and phantom circuits were properly supplied with inductance, or load, coils. This circuit represented a very high development in the art of transposing, loading, and insulating physical and phantom circuits of great length at that time.

29. It has been determined that a phantom circuit made up of No. 8 B. W. G. copper unloaded wires, talks as well from New York to Denver as 69 miles of standard telephone cable containing the usual No. 19 B. & S. copper conductors, unloaded. This would not give good enough results for commercial telephone business, which should not exceed 30 miles of standard cable. But with the four wires loaded, the conversation was as good as that over 28 to 29 miles of standard telephone cable. A New York-to-Chicago, No. 8 B. W. G. copper, unloaded circuit is equivalent to 34 miles of standard cable. The same circuit with telephone repeaters is equivalent to 22 to 24 miles of standard cable without repeaters, but with four similar wires loaded and with telephone repeaters each circuit is equivalent to about 17 miles of standard cable. The efficiency of the loaded phantom circuit, using the same four conductors, is equivalent to about 15 miles of standard cable.

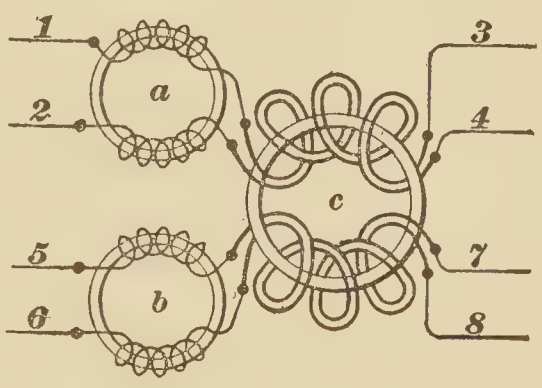

FIG. 11

Not only can three telephone conversations be held simultaneously over the four wires, but each wire can be used for a quadruplex telegraph line; thus, nineteen messages, sixteen telegraph and three telephone, may be simultaneously trans-

mitted over the four wires when there is sufficient business to require it.

30. The connection of load coils in physical and phantom circuits is shown in Fig. 11. The wires *1*, *2*, *3*, and *4* constitute one physical circuit in which is inserted the load coil *a*. The wires *5*, *6*, *7*, and *8* constitute the other physical circuit with the load coil *b*. The load coil *c* is so connected in the circuit as to add inductance to each half of the phantom circuit, but it adds no inductance to the physical circuits. These load coils have a ring-shaped iron circuit made of fine steel wire, the quality of the steel being such as to give very little hysteresis, and the eddy-current loss is kept low by the fineness of the laminations.

TRANSCONTINENTAL LINE

31. The circuits illustrated in Fig. 10 have been extended until they reach from New York to San Francisco as outlined in Fig. 12. The four stations indicated by rectangles contain apparatus similar to that in the Winnemucca station. This circuit consists of four No. 8 B. W. G. copper wires loaded at eight-mile intervals with coils of one-fourth henry each. The transmission equivalent of the lines without apparatus is about 56 miles of standard No. 19 B. & S. gauge standard copper cable conductor. The composite equipment and other apparatus adds an additional loss of about seven miles, making the total equivalent about 63 miles.

32. Vacuum-tube telephone repeaters are located at Pittsburgh, Chicago, Omaha, Denver, Salt Lake City, and Winnemucca. These reduce the transmission equivalent to one-third of the value existing without them; in other words, these repeaters make the resultant equivalent 21 miles of No. 19 gauge standard copper cable conductor.

33. The development of the simultaneous telegraph and telephone art between the time of the opening up of the circuit of Fig. 10 and the time of the opening of the transcontinental line, Fig. 12, was considerable. The telegraph order wires

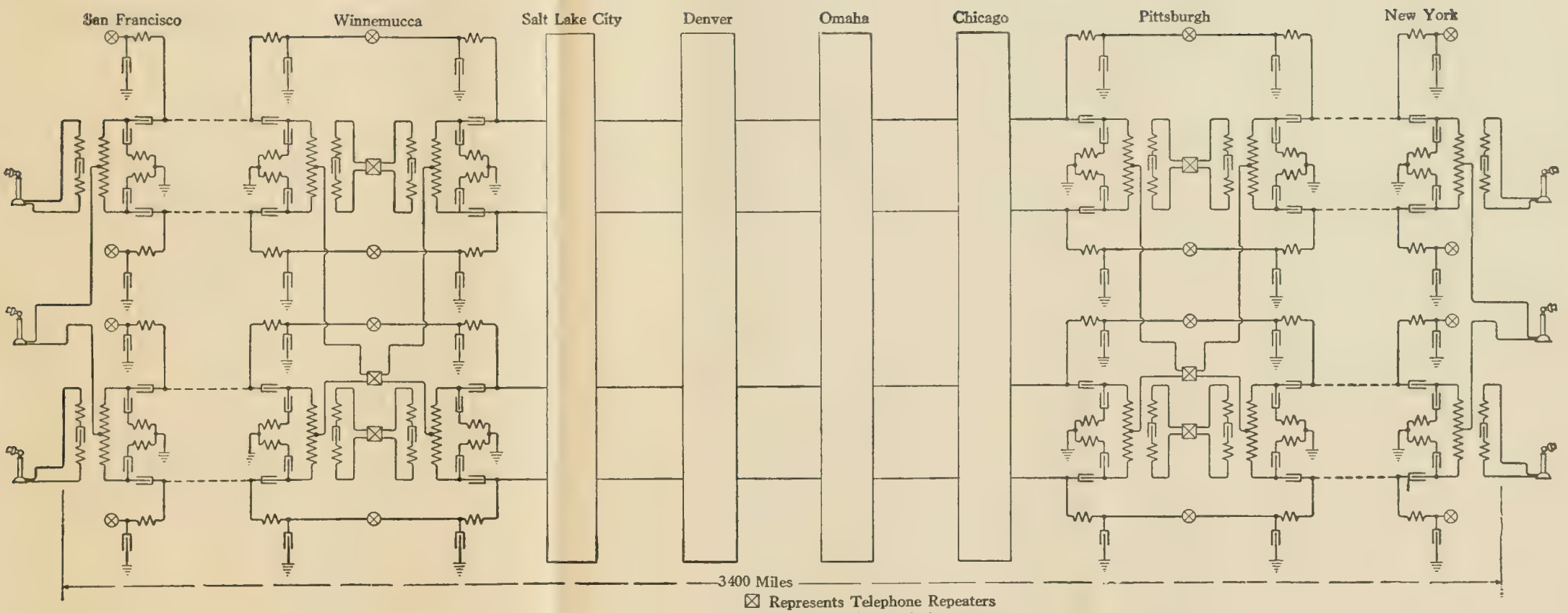

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FIG. 12

have been discontinued. The composite ringers obviate the need of these. The vacuum-tube telephone repeater is probably the greatest single development and is responsible for the present success of long-distance telephony.

TOLL TEST AND MORSE BOARDS

INTRODUCTION

34. The simplex, composite, and phantom circuits that have been taken up in this Section are applied to existing lines to increase the efficiency of the line and permit of simultaneous operation of telephone and telegraph on the same line wires. The business done over such lines is distinctly a toll business; the telegraph circuits, as in the case of the American Telephone and Telegraph Company, are frequently leased to brokers and others who desire private telegraph service. It is very essential, therefore, that these lines be maintained in good order. The line terminals must be so constructed and wired that access can be had to them instantly, and the system must be flexible enough so that in case one of the wires fails it can be readily replaced by another. A practical method of obtaining such results is the connecting of the line wires through toll test and Morse boards.

TYPES OF BOARDS

CORD-TYPE BOARD

35. Jack Connections.—One type of board used for testing and completing circuits employs cords for interconnecting the various circuits. The jack connections of the board are shown in Fig. 13. As indicated in the figure, the jacks are wired in pairs, and double plugs are required to make the necessary connections. The plugs are of the single-conductor

type, and the insertion of a double plug into a set of jacks completes the connection from the outside springs of one jack to the outside springs in the other jack. The inside springs of the jacks break contact with the outside springs as soon as a plug is inserted into the jack.

36. If a double plug is inserted in jack pair *1*, Fig. 13, the cord equipment is extended to the switchboard. A double plug in jacks *2* connects the cord equipment with the outside circuit and at the same time operates the signaling apparatus at

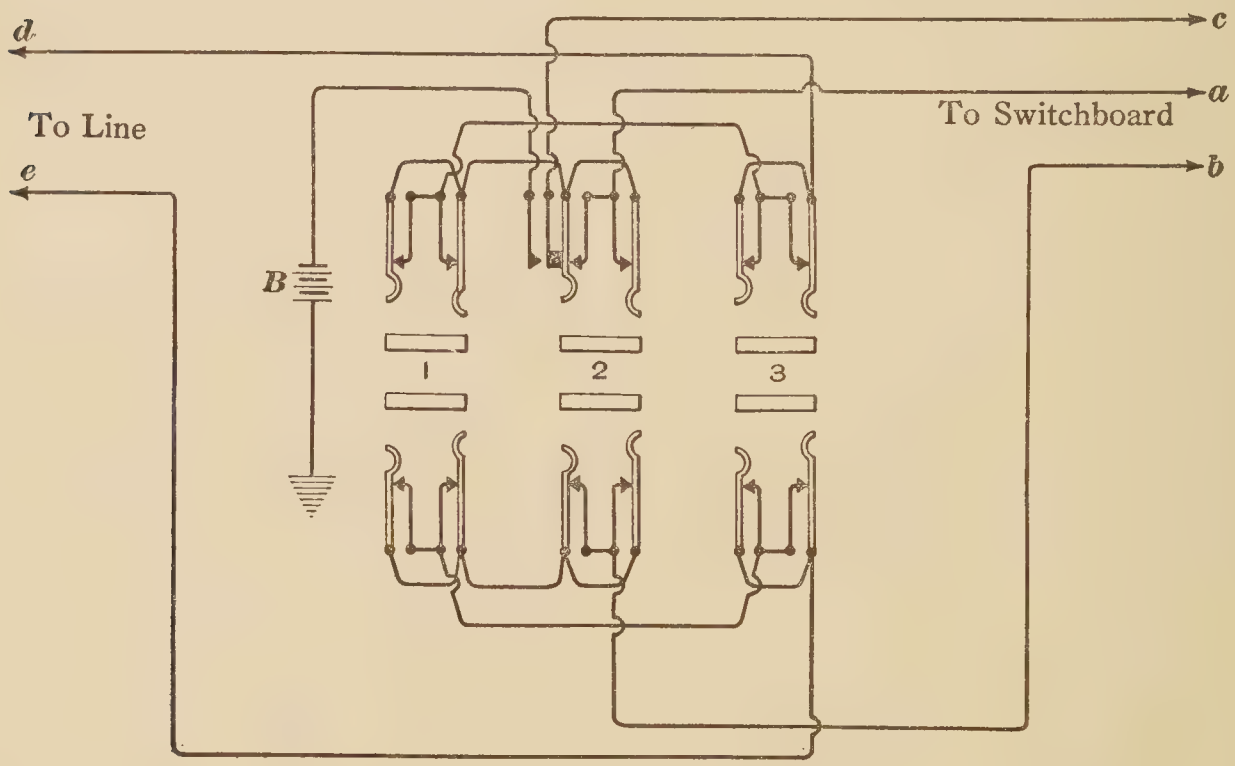

FIG. 13

the toll switchboard. Jacks *3* when connected by a double plug, open the circuit to the switchboard.

The circuit with the first jacks plugged may be traced from *a*, through upper jacks *2* and *1*, cord, and lower jacks *1* and *2*, to wire *b*. With a double plug in jacks *2*, a circuit is first of all completed from battery *B*, through a closed contact of the upper jack *2*, to wire *c* terminating in the switchboard. Another path is also completed from conductor *d*, upper jacks *3* and *1*, upper jack *2*, cord equipment, lower jack *2*, and lower jacks *1* and *3*, to conductor *e*. This circuit remains the same with a double plug in jacks *3*, except that battery *B* is cut off from the sleeve wire *c*.

37. Cord Circuits.—The line shown in Fig. 13 may be composited or simplexed by the arrangements shown in Figs. 14 and 15, respectively. To adapt the circuit of Fig. 13 to composite operation, the double plug *a* of Fig. 14 is inserted

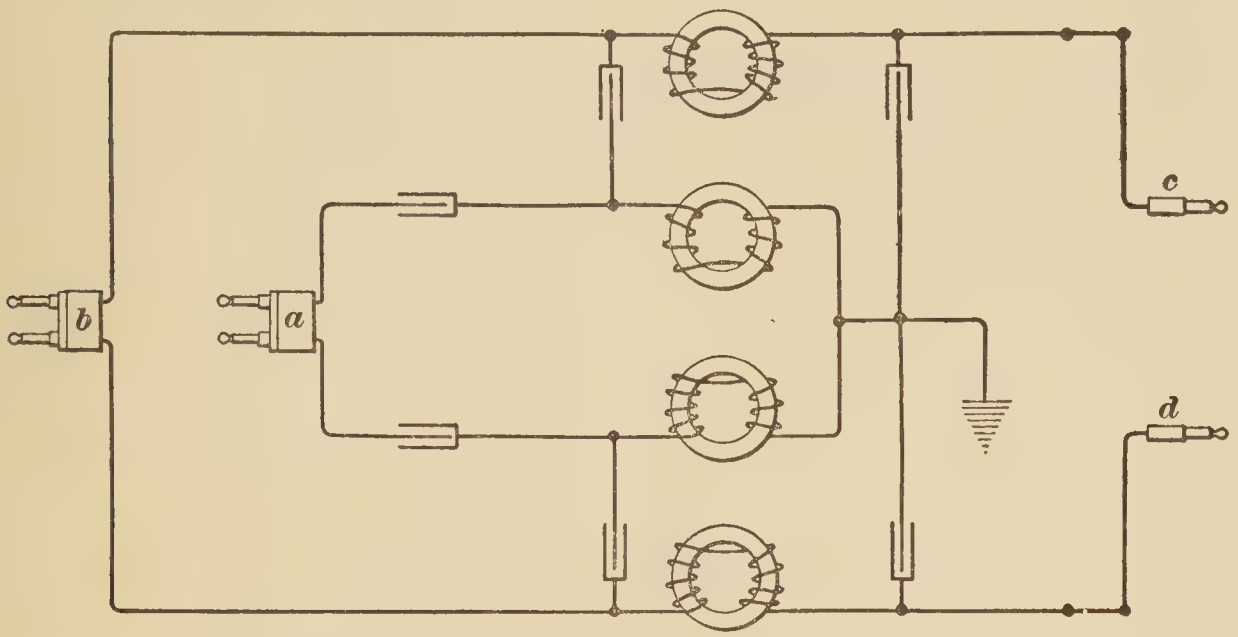

FIG. 14

into jacks *1* of Fig. 13; the double plug *b*, Fig. 14, into jacks *3*, Fig. 13; the Morse legs *c* and *d*, Fig. 14, are extended to the Morse board or to a private subscriber. The circuit resulting from these connections is the same as the composited circuit that has been explained.

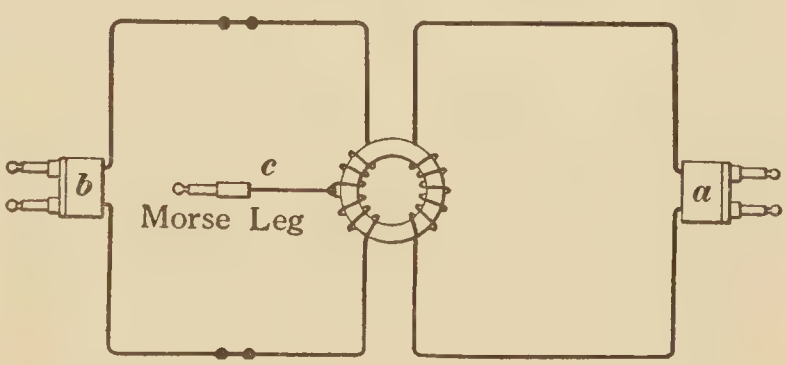

FIG. 15

For simplexing a line, the cord circuit shown in Fig. 15 is used. The plug *a* is placed into jacks *1*, Fig. 13; plug *b*, Fig. 15, into jacks *3*, Fig. 13; and the single-conductor plug *c*, Fig. 15, is connected to the Morse apparatus.

CORDLESS-TYPE BOARD

38. Introduction.—Another type of board, the face of which is shown later in Fig. 22, is a cordless-type board. This board is both a toll test and a Morse board. In wiring it, the

terminals of the subscriber loop, the toll line, and the composite or simplex set are brought independently to jacks in the test board, so that by making the proper cross-connections at this point the complete circuit may be cut through.

39. Subscriber-Loop Wiring.—In Fig. 16 is shown the wiring of a subscriber loop through the test board. At *W* is shown the subscriber loop coming from the subscriber's station, which, after being cross-connected at the main distri-

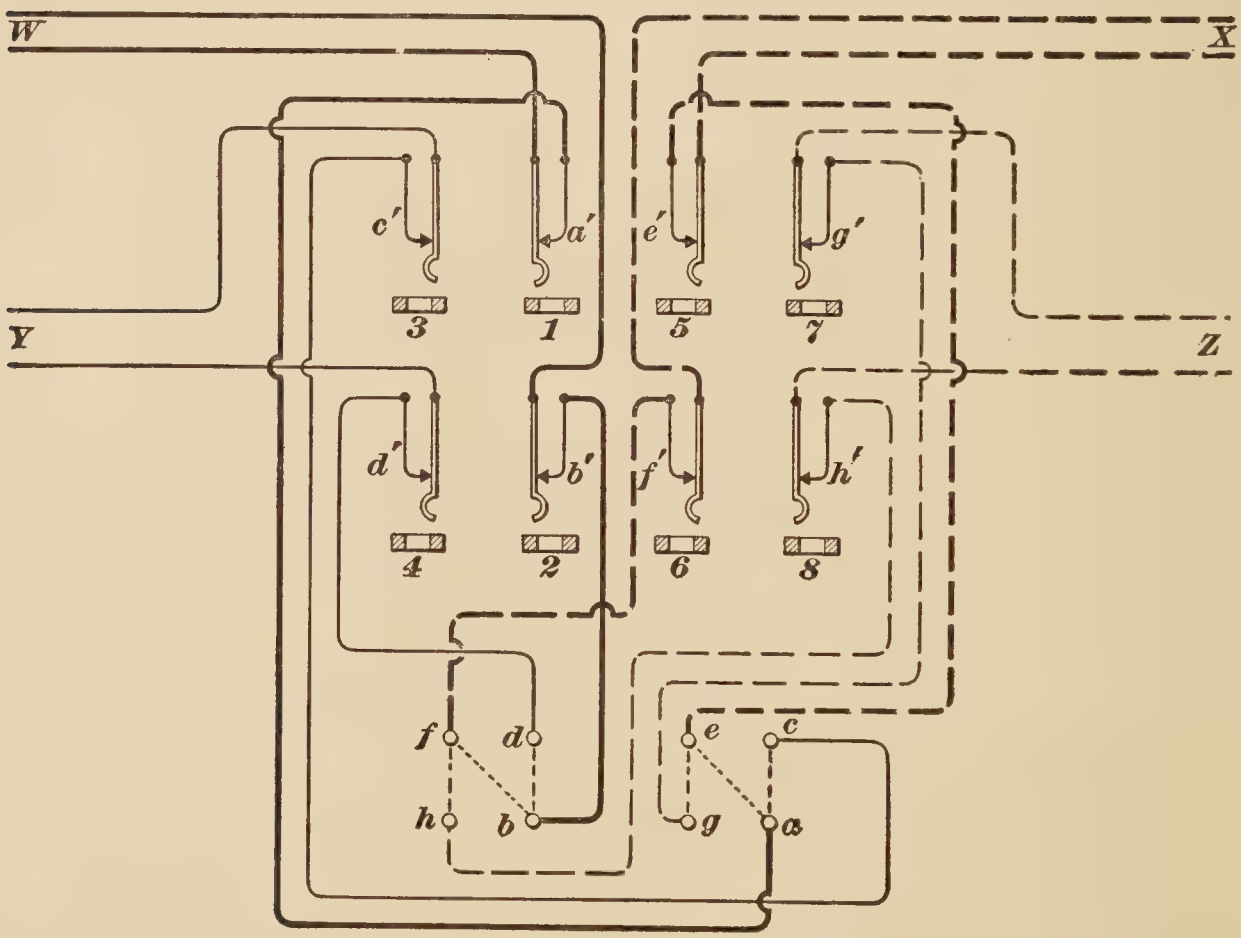

Fig. 16

buting board, is carried through the two cut-off jacks *1* and *2* on the test board to the lugs *a* and *b* on a small connecting rack placed in the rear of the board. If a direct telephone circuit is desired, without Morse, the cross-connection is that shown by the dotted lines *a e* and *b f*. From lugs *e* and *f*, the circuit runs to the cut-off jacks *5* and *6*, respectively, and then along wires *X* to the drop and answering jack on the subscriber board.

Should the use of a composite set be required, lug *a* is connected to lug *c*, lug *g* to lug *e*, lug *b* to lug *d*, and lug *h*

to lug *f*, as indicated by the short-dash lines, instead of lug *b* being connected to lug *f* and lug *a* to lug *e*. In this case, the line runs from the lug *b* through lug *d*, thence through the cut-off jack *4* to the line side *Y* of the composite set; returning, it passes through the cut-off jack *3*, lug *c* and *a*, and jack *1*, back to the subscriber's line *W*. The drop side *Z* of the composite set, which runs to the switchboard, passes through jacks *7* and *8* to the lugs *g* and *h*, respectively, thence through cross-connections *g e* and *h f* and jacks *5* and *6*, respectively, to a drop and answering jack across wires *X*. The line is composited by merely cutting through the proper cross-connections at the back of the board.

The cut-off jacks afford a means of testing various portions of the line, by isolating them for the time being from the remainder of the circuit. When a plug is inserted in a jack, it makes contact with only one spring, the plug not going in far enough to touch the contact point on which the spring normally rests. This contact point is called the *normal contact* of the jack.

40. Fig. 16 also shows the arrangement of wiring the test board for a line leased by a subscriber for his special use. In this case, a toll line *W* passes through jacks *1* and *2*, cross-connections *a c* and *b d*, jacks *3* and *4*, to the toll-line drop *Y*. The subscriber loop *X* passes through jacks *5* and *6*, cross-connections *e g* and *f h*, jacks *7* and *8*, to the subscriber's drop and answering jack across wires *Z*. By inserting a double, or twin, plug, such as is shown later at *A* in Fig. 20, in jacks *1* and *5*, Fig. 16, and a similar plug in jacks *2* and *6*, the subscriber's loop *X* is connected directly to the toll line *W* and the other apparatus is cut off.

41. Testing Lines.—If plugs are placed in jacks *1* and *2*, Fig. 16, the line *W* may be tested toward the subscriber station, the remaining portions being cut off; if plugs are placed in jacks *5* and *6*, the test may be made toward the switchboard on wires *X*, the remainder of the circuit being cut off. The composite set may be cut out by twin plugs placed horizontally so as to connect the springs of jacks

1 and *5*, also jacks *2* and *6*. By inserting twin plugs vertically in jacks *3* and *4*, the line *W* is opened. Twin plugs inserted vertically in jacks *1* and *2* cross the line wires *W*, that is, connect the two sides together. These connections are merely an elaboration of the circuits used by the wire chief in a local office for testing in and out. Some boards do not contain lugs *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*, but *a'* is permanently connected to *c'*, *b'* to *d'*, *g'* to *e'*, and *h'* to *f'*; this simplifies the connections.

Should it be desired to use the composite set (or simplex set) on another line, two double cords terminating in double plugs are used. One end of the one cord is inserted vertically in jacks *3* and *4* and the other end in the jacks corresponding to *1* and *2*, but on the line on which it is desired to use the set. Also, one end of a second cord is placed in jacks *7* and *8* and the other end of this cord in the jacks corresponding to jacks *5* and *6*, but on the drop side of the particular line on which it is desired to put the set.

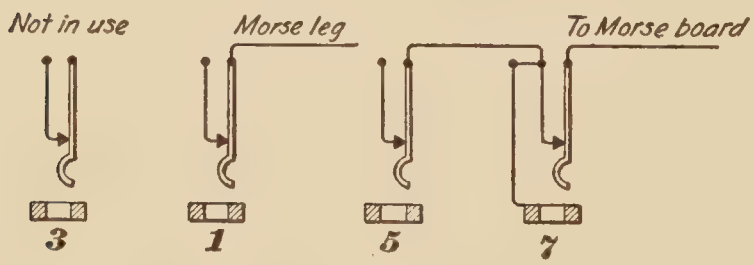

FIG. 17

42. Arrangement of Morse Legs.—The Morse legs of the various sets are usually brought to jacks in the test panel, or if there is no room there, to an extra panel mounted for that purpose. One arrangement is that shown in Fig. 17, which uses one jack *5* as the terminal of the line from the Morse board (the description of which will follow). Jack *7* is then arranged to act as a *looping-in jack*, by means of which a Morse set (relay and key) may be inserted in series with the Morse circuit in order to answer telegraph subscribers' calls or do any other business on the circuit.

Looping in is accomplished by means of two cords terminating in a single plug with an extra sleeve insulated from the point. This sleeve makes contact with the sleeve of the jack, the normal contact and the sleeve of the jack being connected together as shown at jack *7*. The sleeves, or *collars*, as they are frequently called, are usually dead, but they can be used if required. The Morse legs of the composite set are brought to

jacks corresponding in position to jacks *1* and *2* in Fig. 16. Under normal conditions, a cord from jack *1* to jack *5*, Fig. 17, is necessary to keep the circuit closed. To move a telegraph subscriber from one Morse leg to another, the operator pulls out the cord from jack *1* to jack *5*, inserts a plug attached to one end of a single patching cord in jack *5* and the plug attached to the other end in the Morse leg jack desired, corresponding in position to jack *1*.

43. Morse Board.—The Morse business necessitates the ability to connect a telegraph, or Morse, battery to any of the lines, or to remove it, as the case may be. For this reason the Morse board has been devised. This board is simply one or more panels generally in the same board as the toll test panels carrying horizontal rows of from four to six jacks, the connections of which are made entirely with a view to facilitating various Morse tests and connections. A single row of jacks in a simple Morse-board panel is shown in Fig. 18. The line coming to the jack *L* is a cross-connection wire over to the test panel, where it may be connected, as shown in Fig. 16, like one of the conductors *Y* to jacks *3* or *4*; or if the Morse wire is to be one side of a composite circuit, it will come to jack *7*, Fig. 17.

The contact of a jack that is permanently connected, or *strapped*, to the sleeve of the same jack is called simply the *normal* of the jack. Thus, the contact *x*, Fig. 18, is the normal of jack *L*. Because the normal *x* is connected to the sleeve, this jack *L* may be used as a looping-in jack by the Morse operator or monitor. From the normal *x* of jack *L*, the line goes to the normal *n* of jack *B*, spring *e*, one side of subscriber's loop, his instruments, and back on the other side of the loop to spring *f* of jack *A*. The normal *o* of jack *A* is connected to the normal *y* of jack *J* and the line receives current through the spring of jack *J*, which current goes through a lamp of suitable resistance mounted in a bank of lamps, and through the battery to the ground.

44. Test for Open Circuit.—To make a test for an open circuit, the Morse monitor cuts in his test set (key, relay, and sounder) by means of a two-contact plug inserted in jack *L*,

Fig. 18. A twin plug is then inserted in jacks *A* and *B*. This connects spring *e* to spring *f*, and sleeve *u* to sleeve *v*; in other words, the subscriber's loop is short-circuited and a circuit is now closed from the normal *x*, through the sleeve *u*, the sleeve *v*, to the normal *y*. If this closes the circuit through

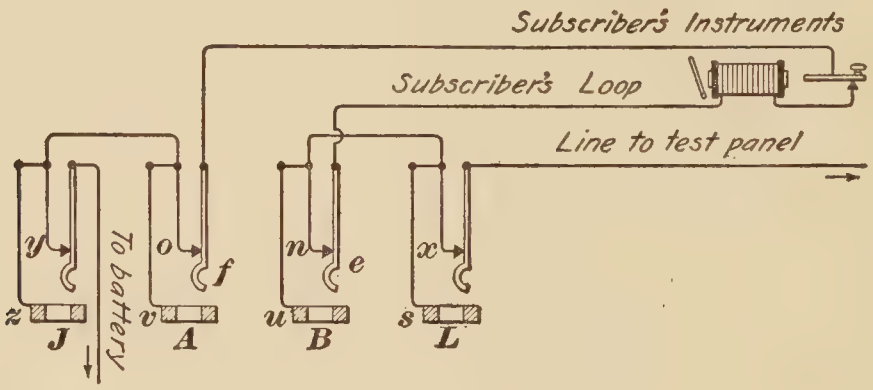

Fig. 18

the test set, the line is probably open in the telegraph subscriber's office. If this does not close the circuit through the test relay, a single plug, connected through the test set to the side of the plug making contact with sleeve *s*, is inserted in a grounded jack, a number of which are provided for use in testing. If the test set now closes, the line is open toward the

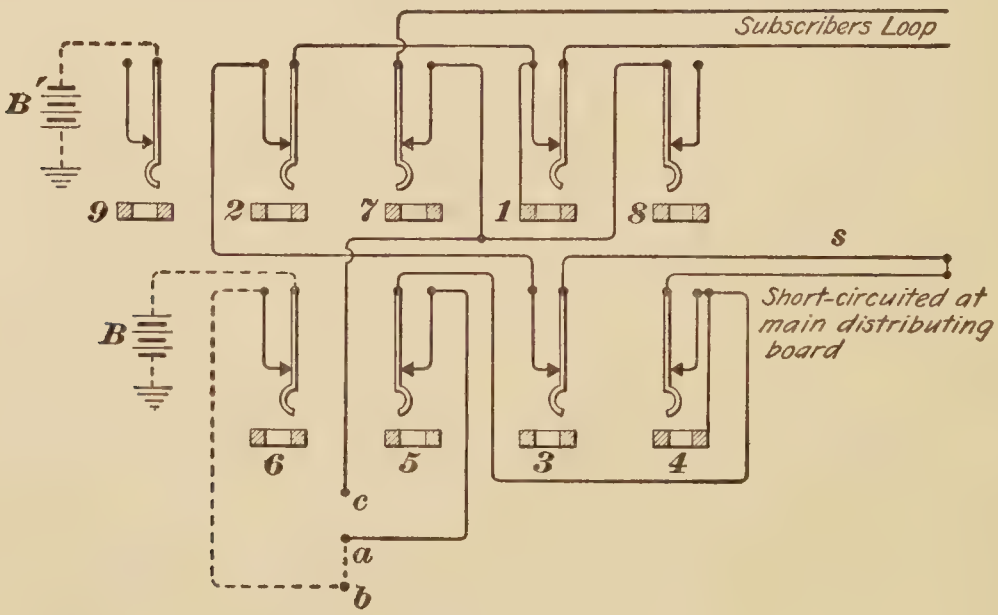

Fig. 19

test panel. If this does not close the test circuit, the battery fuse is probably burned out or there is some trouble in the office wiring, to remedy which proper steps should be taken.

45. Wiring of Morse Board.—The wiring of a Morse board is shown in Fig. 19, where the subscriber loop coming in

from the main distributing board is shown. One side of the loop passes through jack *1*, jack *2*, and jack *3*, to the main distributing board, where it is short-circuited and returns through jack *4*, jack *5*, lug *a*, lug *b*, jack *6*, to the Morse battery *B*, which usually consists of thirteen storage cells in series. The opposite side of the loop, after passing through jack *7*, ends at jack *8* and lug *c*. The remainder of the circuit is wired through the test board, as shown in Fig. 16. All jacks have collars, but they are used only where they are shown connected to the circuit.

The cord-circuit equipment consists of the regular testing circuit shown in Fig. 20, in which a twin plug *A* is wired to a

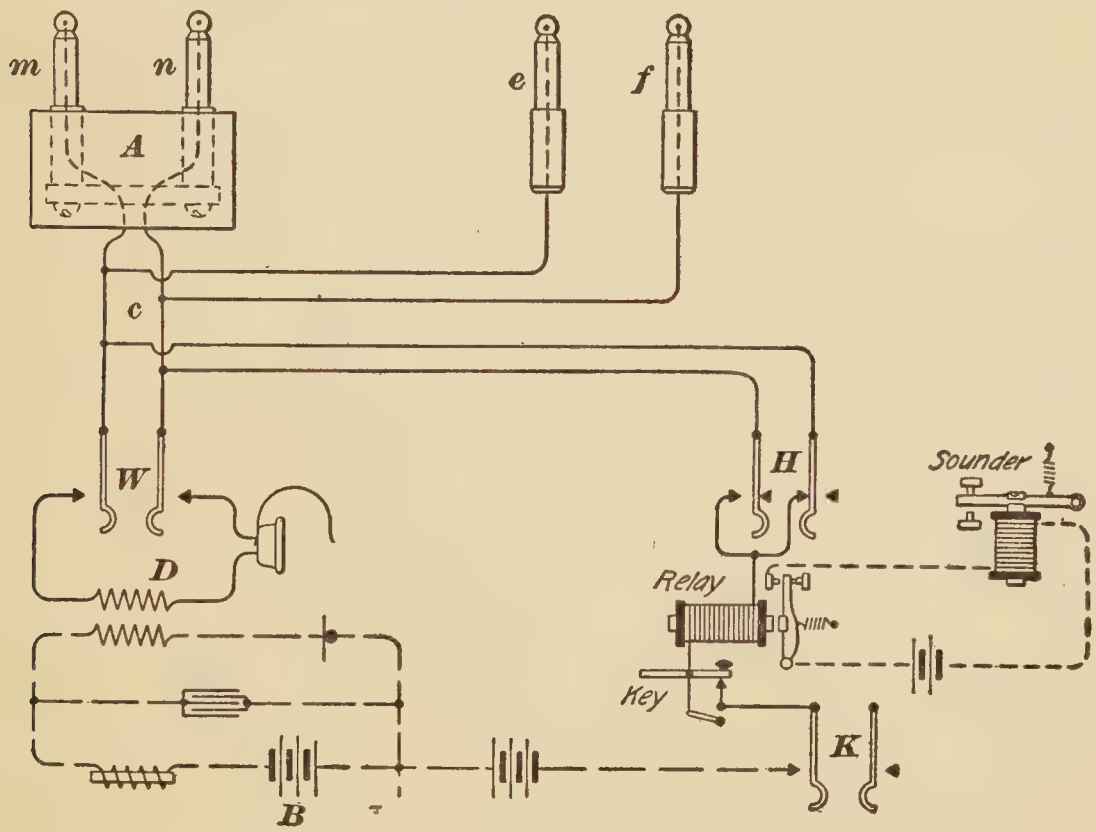

FIG. 20

listening key *W*, by means of which the telephone circuit *D* may be cut in. Bridged to each strand of the cord *c* is a single-strand cord attached to the single plugs *e* and *f*; they are used to test each side of the line independently of the other. The apparatus used for making these tests consists of an ordinary telegraph relay, key, and sounder. With one key *K* closed and the other key *H* in normal position, the Morse set is connected to plugs *m* and *e*; with the left contact of the key *H* closed, the Morse set is connected to plugs *n* and *f*. For example, if

the twin plug *A* or the single conductor plugs *e* and *f* are inserted in jacks *3* and *4* of Fig. 16, each of the two line wires *Y* may be tested telegraphically by means of the telegraph apparatus shown in Fig. 20. The other testing apparatus

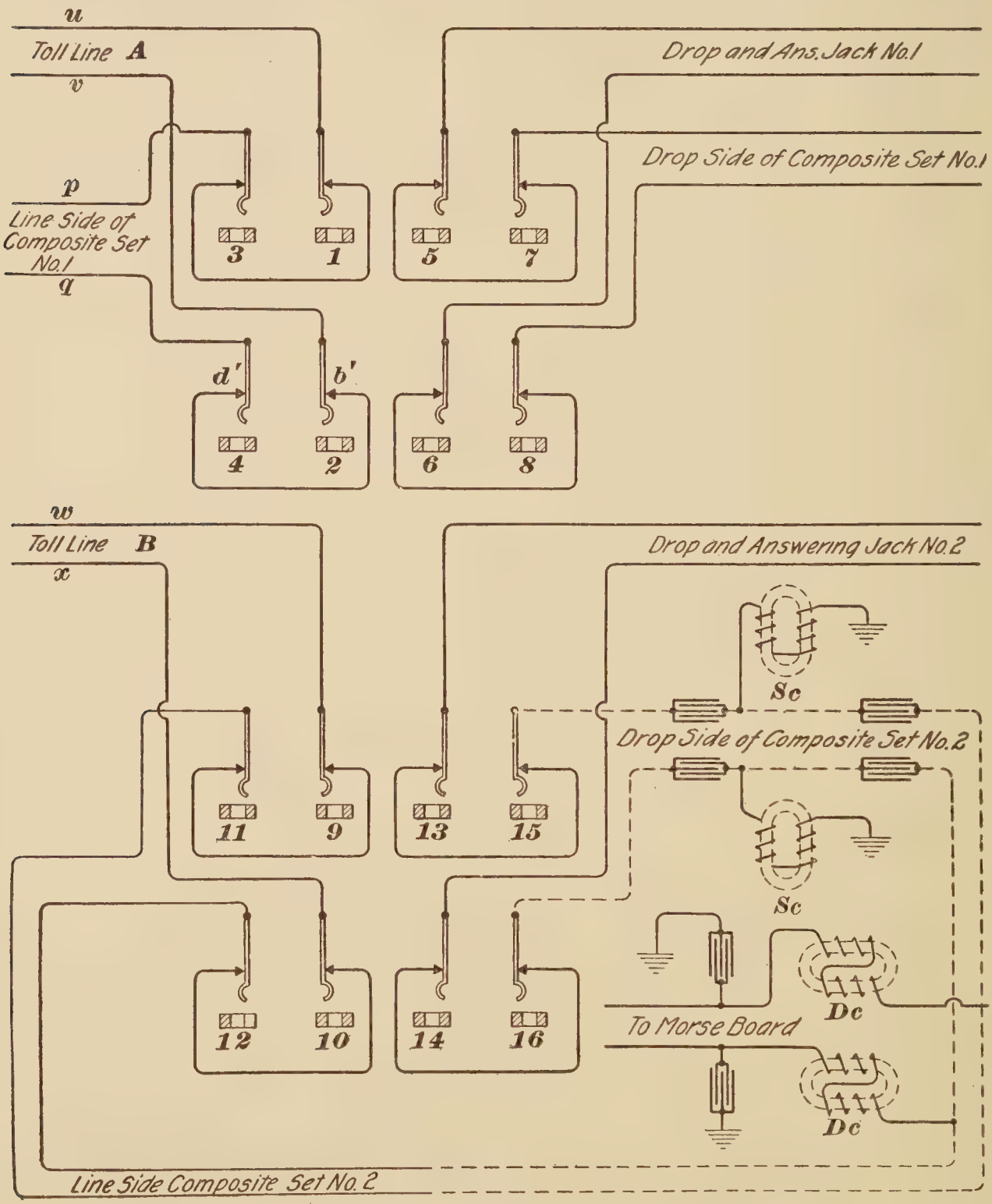

FIG. 21

consists of a Wheatstone bridge wired to a plug, by means of which the regulation loop tests for grounds and crosses are made. No provision is made for testing switchboard trouble by means of a test circuit, similar to that used by the local

companies, the long-distance companies not having adopted this class of test.

46. Patching.—Besides being used for testing, and making the proper connections between subscriber loops and toll lines, and between toll lines, the test board is used for what is called patching. This is resorted to when, as the result of a storm, only a few wires are in working condition, and circuits have to be made up of wires that are not mates. It is done by means of the plugs *A*, *e*, and *f*, Fig. 20. For example, suppose that in Fig. 21 conductors *u* and *w*, one on each of the toll lines *A* and *B*, are defective and that it is desired to patch up a line by the use of the other conductors *v* and *x* on each of these lines. It will be necessary to connect the drop and composite set properly to these conductors *v* and *x*. To do this, let it be supposed that the drop and answering jack No. *1* usually connected to line *A* is to be retained. A single conductor cord has one plug inserted in jack *3* and the other plug is inserted in jack *10*. A circuit is thus made from the good conductor *x* through jack *10*, the patching cord and jack *3*, conductor *p* of the line side of the composite set No. *1*, the upper conductor of the drop side of composite set No. *1*, jack *7*, jack *5*, drop and answering jack No. *1*, jack *6*, jack *8*, the lower conductor of the drop side of composite set No. *1*, conductor *q* of the line side of composite set No. *1*, the normal contacts *d'* and *b'* of jacks *4* and *2*, to the good conductor *v* of line *A*.

The connecting-rack lugs, as shown at the bottom of Fig. 16, have been omitted in Fig. 21 for the sake of simplicity. Extra batteries *B'*, Fig. 19, of various potentials and polarities are wired to the springs of some spare jacks so that one plug of a single patching cord inserted in one of these jacks and the other plug in jack *J*, Fig. 18, and making contact with the sleeve, the line in Fig. 18 may be connected to any one of the extra batteries.

The composite set, shown in Fig. 21, is the old method in which four separate retardation coils are used instead of two. The theory of operation is the same as that of the two-coil type.

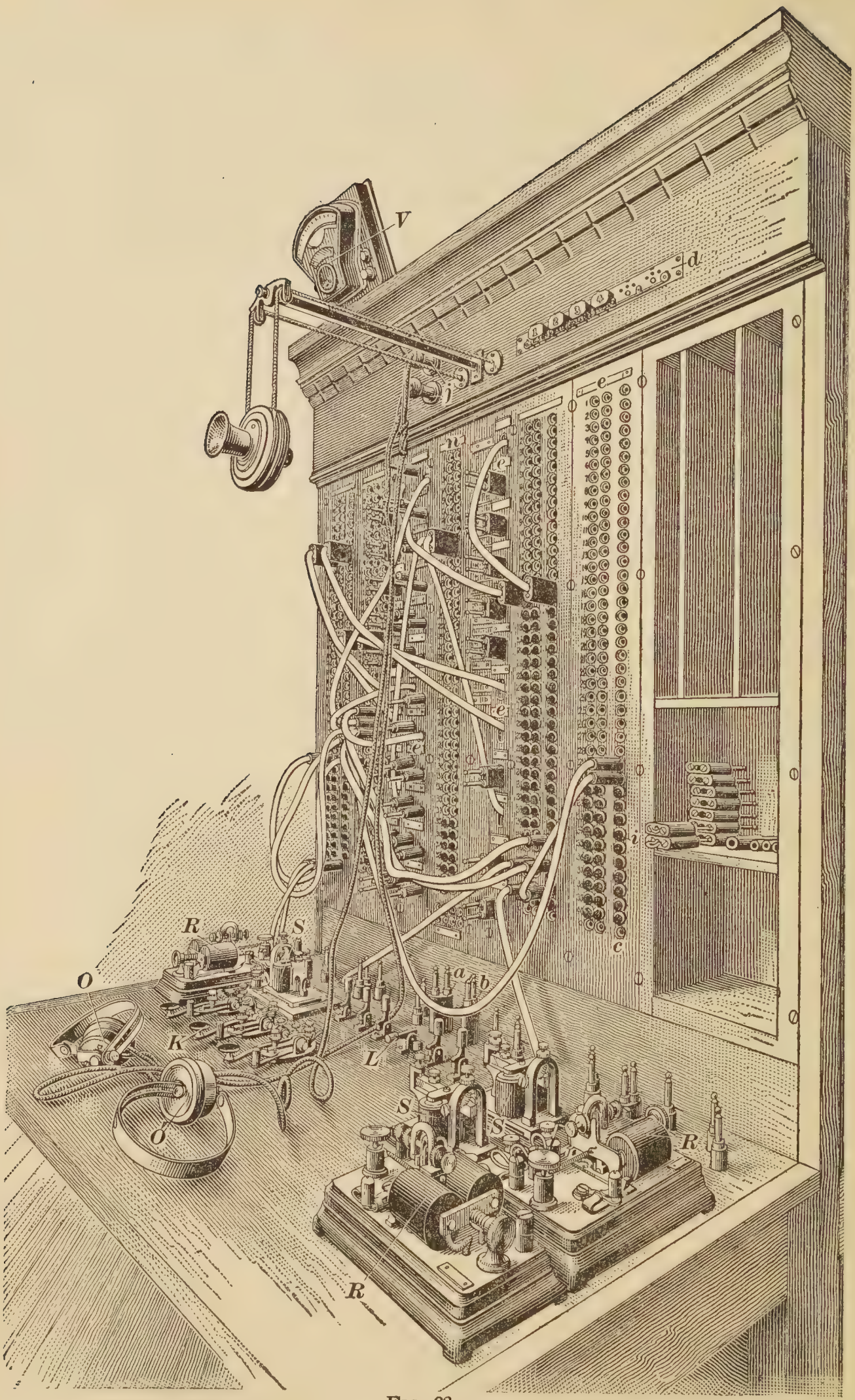

FIG. 22

47. Description of Morse Boards.—In Fig. 22 is shown a Morse and toll test board used at an intermediate station. On the key shelf are three complete Morse sets, each consisting of a relay *R*, key *K*, and sounder *S*. One set is permanently connected in a cord circuit while the other two sets may be connected to any circuit for testing purposes. On the rear of the shelf are a number of plugs used for various purposes and two twin plugs *a* and *b* associated with the receivers *O* and *O'* that are connected by flexible cords with the operator's plugs and jacks at *j* near the top of the board. The twin plugs may be used to listen or talk on any circuit in whose jacks they are inserted. A single transmitter hangs by flexible cords from the top of the switchboard, while a voltmeter *V* is mounted on the top of the board where it can be read when the wire chief is standing in front of the board making tests. A row of keys used for various purposes in connection with the telephone head-set, is shown at *L*. One may be used to cut in the battery, one, a listening key, connects the head-set across a pair of cords, and another cuts in the drop of a trunk to the toll switchboard.

The vertical rows of single jacks, such as *c*, are sometimes called *transfer jacks;* Morse batteries may be connected to some of these jacks. The voltmeter *V* may be connected to plugs for testing the battery or other circuits and a milliammeter is also usually provided and connects to plugs for measuring the current in the Morse circuits. A Wheatstone bridge set is generally provided and is wired either to the cords or to the keys and connected thereby to the test cords that are used for various purposes, such as talking, testing with voltmeter, etc.

In case of trouble on a leased Morse loop, the telephone set may be used to communicate with the Morse subscriber through the same subscriber's regular exchange telephone. The jacks in the row *n* are connected to various local circuits.

48. The framework of a Morse and test board is about the height of that of a local switchboard. The jacks are mounted in rows on hard-rubber strips, which are, in turn, screwed to the wooden framework. There are several holders *e*, Fig. 22,

for cards bearing the name of the subscriber loop or toll line, as the case may be. At the top is mounted a row *d* of drops to which are wired lines from the toll board used in calling the test board. Spare jacks associated with these drops are used in answering calls on these lines. The equipment of a separate Morse board differs from that of a test board only in the fact that the keyboard is equipped with telegraph apparatus for use in handling the Morse business. The section is also equipped with the regulation telephone circuit. In Fig. 22 there are forty-one horizontal rows of jacks. When composite wiring is not used, each panel has a capacity of twenty rows east and twenty rows west, or twenty through circuits. When compositing is used, every other row of jacks is taken for the drop side and the intervening rows for the line side of the composite set, as shown in Fig. 16. The forty-first row of jacks is a spare row. The holes containing wooden plugs *i*, Fig. 22, are not now provided with jacks, but they can be when there are enough lines and business to require them. This particular board can be equipped with another complete panel when necessary.

49. Connecting Telegraph Repeaters.—Telegraph repeaters of the American Telephone and Telegraph Company when used on long circuits such as are made up of two or more sections of composited wires are connected up in two ways—either temporary or permanent. In large offices, repeaters are connected in boards of this type permanently; while at the intermediate points they are usually connected in the circuit temporarily. When connected permanently, the repeaters are wired back to the distributing board, where, by means of jumpers, connection is made with the Morse side of the composite sets. When connected temporarily, they are wired to cords and plugs, placed in a special panel on the Morse board. The Morse side of the composite sets is wired to a separate row of jacks, so that by merely inserting repeater plugs in these jacks, the proper connection can be made.

JACK-TYPE BOARD

50. Equipment and Possible Combinations.—A third and newer type of board consists of four panels to a section. Each panel contains ten jacks in a horizontal strip, and about twenty-six such horizontal strips one above the other. In this board the various types of circuits are wired to jacks. All associated jacks are in vertical rows—in pairs in the toll board, and single rows in the Morse board. In large offices Morse sections alternate with toll sections. In small offices both toll and Morse circuits are contained in a single section.

A greater variety of circuit arrangements is possible with the jack-type board than with the older types. Some of these circuits are indicated in Figs. 23 and 24. Other of the circuit combinations are taken care of in a manner similar to those indicated, with the addition of the jacks that are essential for the purpose. Boards are made up of groups of circuits of the same type arranged together; for instance, all the through toll lines for test only, are kept together, likewise all the terminating toll lines are together. The space allotted to the various types of circuits depends on the number of each type that must be provided.

51. The following list gives some of the types of circuits handled: Through toll line for test only; terminating toll line not arranged for phantom, simplex, or composite; terminating phantom toll line not arranged for composite apparatus; terminating toll line arranged for phantom apparatus; terminating toll line arranged for simplex apparatus; terminating toll line arranged for composite apparatus; terminating phantom toll line arranged for composite apparatus; terminating toll line arranged for composite and phantom apparatus.

Morse subscribers' loops terminate on plugs in the key shelf of the boards. If the installation is large there are trunks to other positions and trunks from the toll test to the Morse board. Local trunks to the toll switchboard are provided, also jacks for converting combined terminal and intermediate composite sets. Each Morse leg or line has two jacks, which

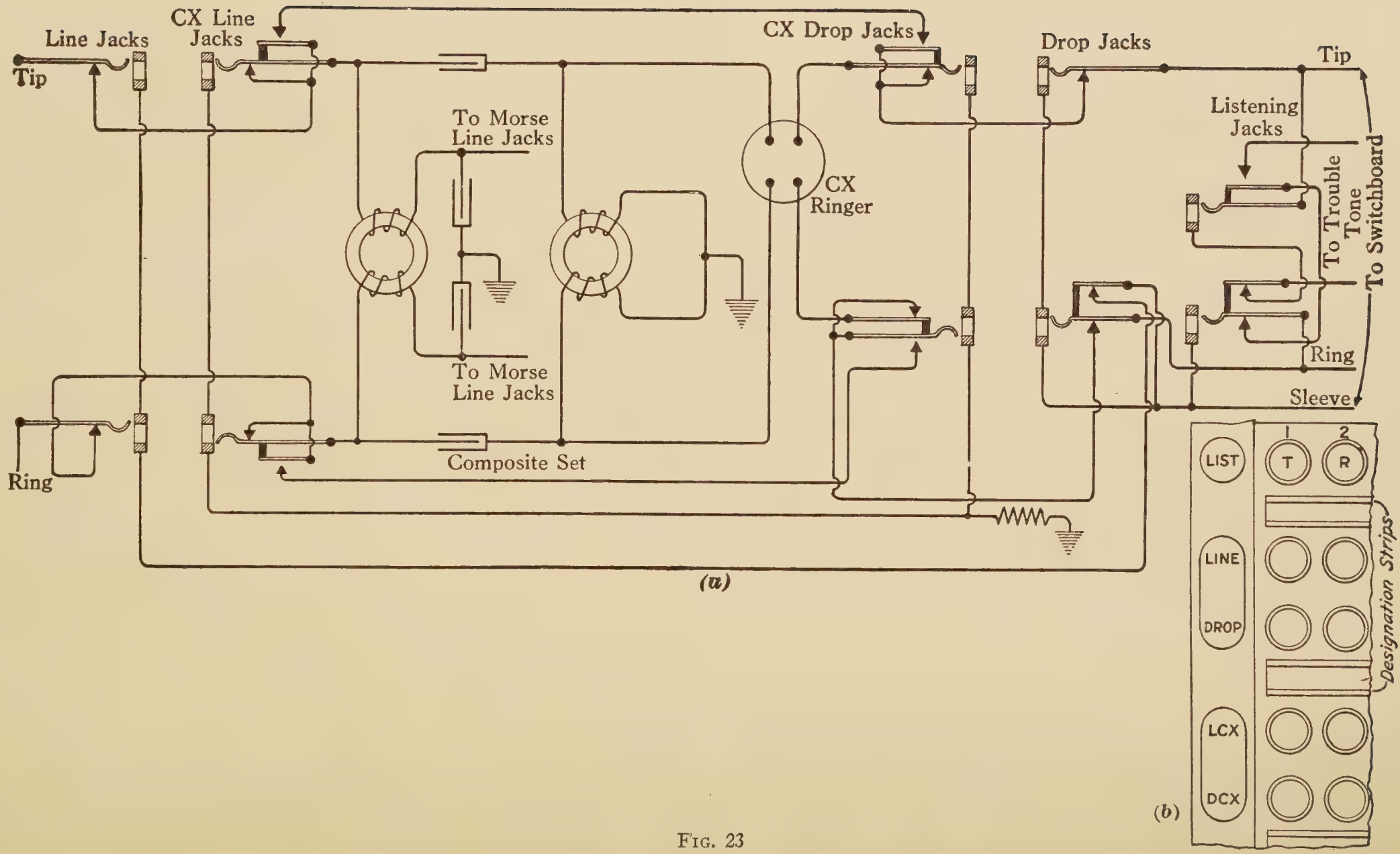
Line Jacks
Tip
CX Line Jacks
CX Drop Jacks
Drop Jacks
Tip
Listening Jacks
To Morse Line Jacks
CX Ringer
To Trouble Tone
To Switchboard
Ring
Sleeve
To Morse Line Jacks
Composite Set
Ring
(a)
LIST
T
R
1
2
LINE
DROP
LCX
DCX
Designation Strips
(b)

FIG. 23

are between the composite sets and the duplex set or subscribers' line circuit, for patching purposes.

Jacks for testing artificial line networks of telephone repeaters are provided, also jacks for monitoring on lines equipped with telephone repeaters. Morse line circuits are in the toll

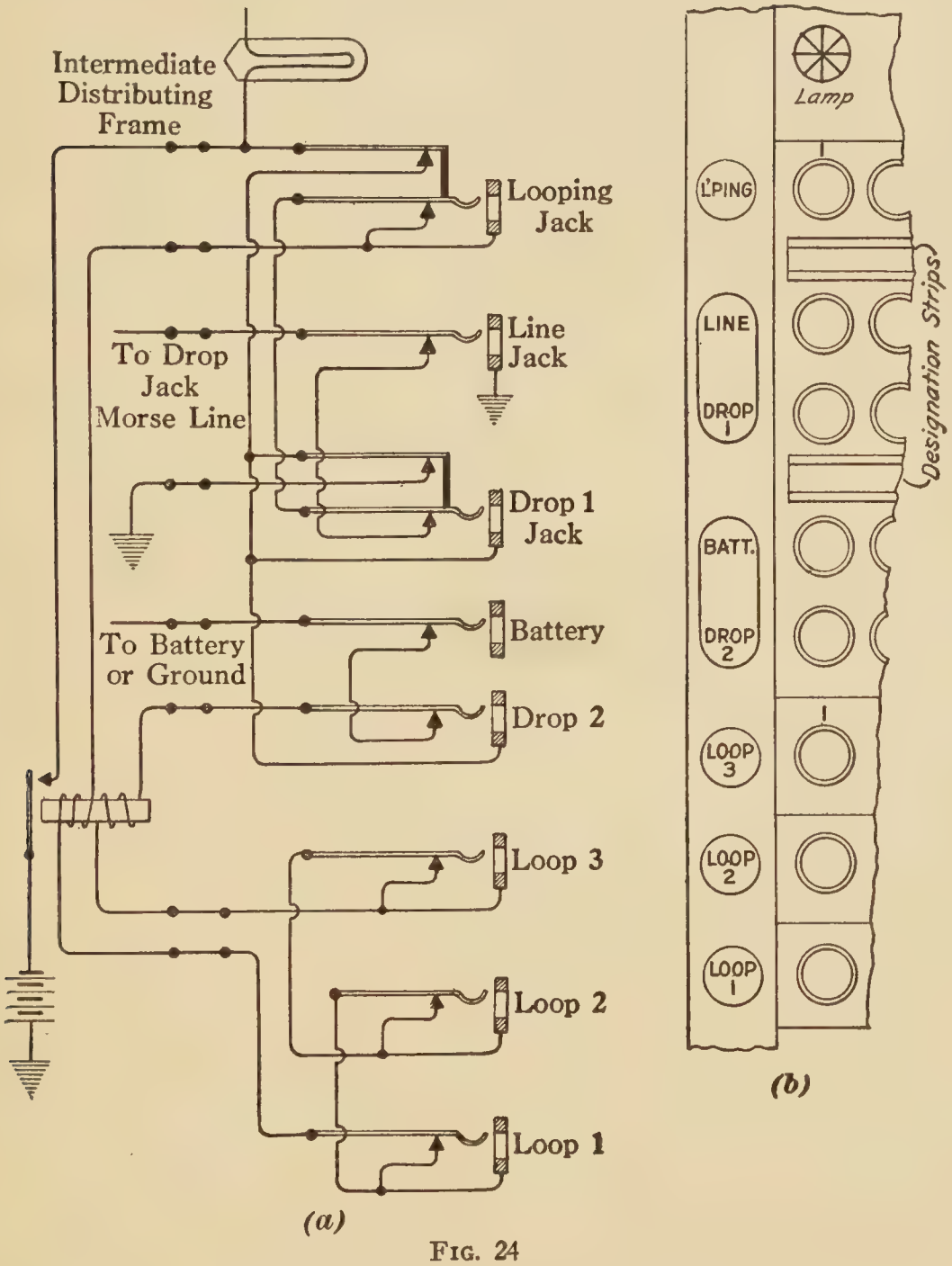

FIG. 24

test board in small installations. The duplex jacks are in the Morse board if the installation has separate toll and Morse boards. Miscellaneous jacks are provided in both the toll and the test boards.

52. Each key shelf at a toll test-board position has a combination voltmilliammeter, Wheatstone bridge, and two

telegraph sets consisting of key, relay, and sounder, with the cords, plugs, and switching keys for connecting them to the line jacks for testing. Each key shelf at a Morse board position has two telegraph test sets connected through switching keys to test cords and plugs. One additional test set consisting of a key, relay, and sounder is wired through looping jacks to a double-conductor plug.

53. Circuits.—Fig. 23 (*a*) shows a terminating toll line composited, a sample of the various types of circuits in the toll test board. View (*b*) shows an assembly of jacks in a panel; other similar terminating toll lines would be in rows of jacks to the right of the two rows illustrated in view (*b*).

54. Fig. 24 (*a*) shows a circuit arrangement of a Morse terminal arranged for single-line working. The subscriber's loop is connected to it by a cord and plug. If this line terminal is to be used on a duplex, the line jack connects to the sending leg of a duplex, and the battery jack connects to the receiving leg of the duplex. View (*b*) shows the panel arrangement of the various jacks. The jacks in view (*b*) correspond in position to those shown in view (*a*).

TELEGRAPH OFFICES

Serial 2115 Edition 1

TELEGRAPH-OFFICE LAYOUTS AND WIRING

SMALL-OFFICE LAYOUTS

SMALL-OFFICE REQUIREMENTS

1. A large number of small telegraph offices are operated jointly with railroad offices and are planned to provide the necessary facilities for efficient traffic operation and wire test work with a minimum cost for such installations and maintenance.

In the consideration of a small office, all wiring and cabling is so planned as to meet present needs as well as to provide for future growth so far as practicable. Even in offices of this class it is the practice to conceal wires and cables as much as possible, utilizing conduit and molding for such purpose. Careful consideration is given to the type of circuits and equipment to be installed.

In railroad telegraph offices and in some of the smaller commercial branch offices, operators are required to perform other duties in addition to the sending and receiving of telegrams. Hence, the layout for such an office is so planned that the aisles between operating positions are short, straight, and unobstructed, permitting free access from one location to another with the least delay or inconvenience.

WIRING DATA

2. Wire Installation.—About the most important item in making office installations is the wiring and cabling work. This work must be done in a thorough manner and the insulation maintained as perfect as possible; particular care being taken to run wires and cables where they will be as inconspicuous as

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practicable. Conduit or molding is preferable for this use. It is desirable to bore holes only where absolutely necessary. The sizes of the holes should be such as to permit the easy pulling of wires and cable without abrasing the insulation or sheath and without causing any bind.

Care should be exercised, when boring through a wall or partition having a finished surface on the opposite side, so that there will be no splintering or cracking plaster due to undue pressure on the bit brace. The splintering may be avoided by removing the bit after the bit shows through and then finishing the bore from the opposite side. If this is not convenient a separate wood block is held firmly against the finished surface on the opposite side. Careful measurement and level drilling will enable a cutting to be made from either side at will.

Wires should not be installed under windows or adjacent to radiators where the wires are likely to be damaged from rain blowing in or from steam leaking from the heating system. If it is necessary to put wires in such places, suitable encased cable should be used, or the wires protected by conduit.

3. Parallel Runs and Cross-Overs.—Running of wires parallel to foreign ones, such as electric-light wires, should be avoided as much as possible. This also applies to the running of wires parallel to gas or water pipes. There should be liberal clearance between the wires when it is necessary to run them together. A clearance of at least 2 inches should be made between open electric-light wires and telephone or telegraph wires. Between telegraph wires and electric-bell wires, signaling wires, pipes, or electric-light conduits the clearance should be at least $\frac{1}{2}$ inch.

At points where telegraph wires cross gas pipes, electric-light conduit, metal work, electric-bell or other signaling wire, and the clearance is less than $\frac{1}{2}$ inch, the telegraph wires should be protected by using one layer of rubber tape and one layer of friction tape or woven conduit. Woven conduit should always be secured by tape, clamp, or fastener.

Water pipes are liable to sweat under certain conditions. Where practicable, therefore, water pipes should be crossed

above rather than below. Where the wire is within $\frac{1}{2}$ inch of the pipe, the wire should be covered with one layer of rubber tape and one layer of friction tape. The wires should be run

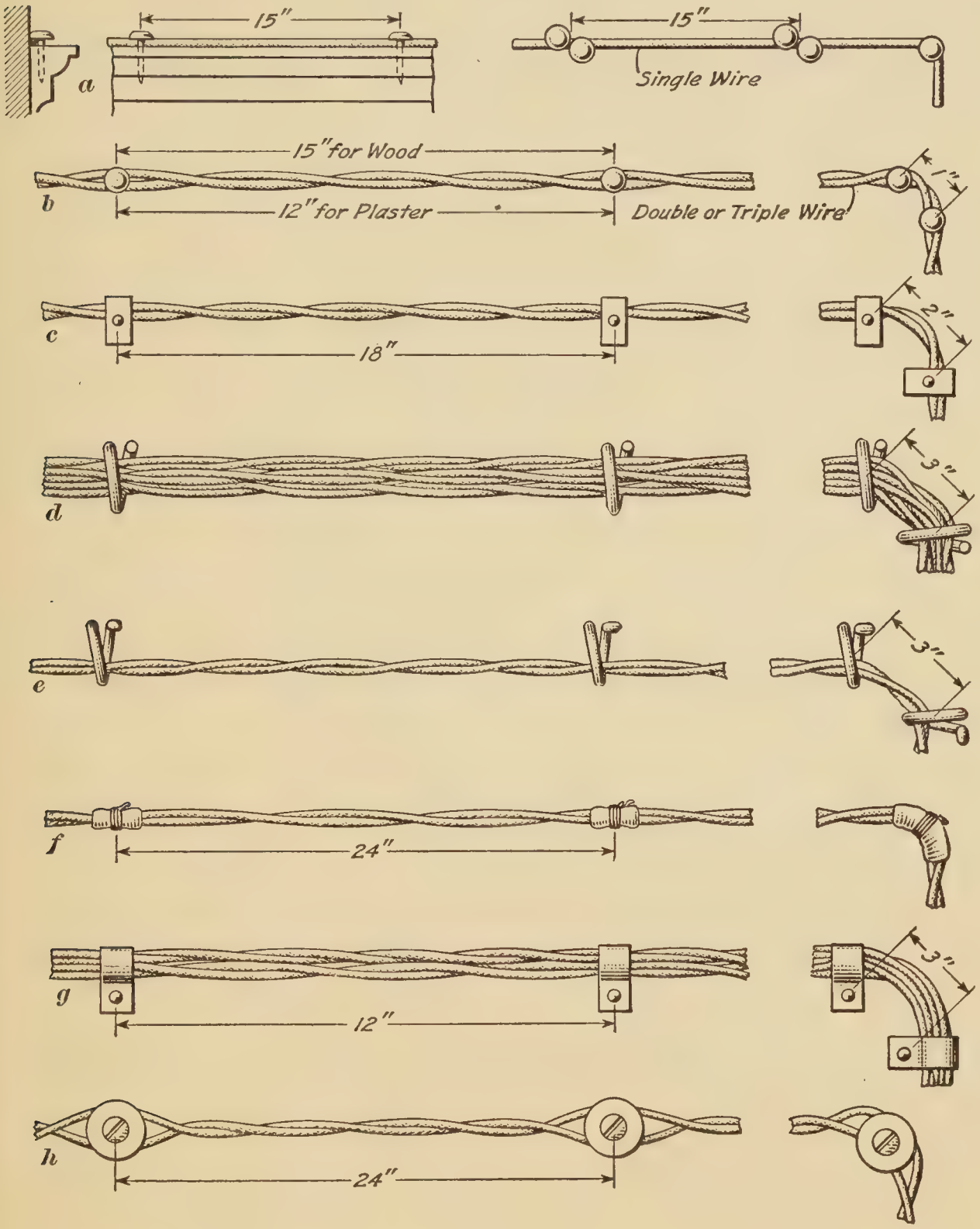

FIG. 1

in porcelain tubes at points where they cross steam pipes, and are within $\frac{1}{2}$ inch of the pipes.

When telegraph wires must cross open electric-light wires, the telegraph wires are run in porcelain tubes at points of crossing.

No protection is required when the wires cross wooden electric-light molding. However, the wires should not be fastened to the molding.

4. Methods of Fastening Wires.—There are various ways of fastening wires and maintaining the proper spacing. On finely finished surfaces, single, double, or triple inside wires are fastened with $\frac{7}{8}$-inch milonite nails to woodwork, masonry, hollow tile, or plaster block, and with inside wire cleats on plaster on wood lath, and on plaster board. When several wire runs are bunched together they are fastened to the surface by means of a clamp and a milonite nail or woodscrew.

On roughly finished surfaces, the wires are carried in bridle rings or approved equivalents. In the case of woodwork, plaster on wood lath, or plaster board, the bridle ring is screwed directly into the material; in other cases it may be necessary to use expansion shields or other methods of fastening the ring to the surface.

Examples of the various types of fasteners and the spacing between them are shown in Fig. 1. The use of milonite nails and the spacing between them is shown at *a* and *b*. Wiring with inside cleats is shown at *c*. The usual spacing between cleats is 18 inches. In furring on metal ceilings, however, the spacing should be 12 inches. The use of bridle rings is shown at *d* and *e*. When tie wires with screws or nails are used they are attached and spaced as shown at *f*. Clamp supports are shown at *g*. The use of knobs is shown at *h*.

5. Cable Forming and Lacing.—The terms forming and lacing are applied to the work of leading wires out of a cable at short spacings for the purpose of distributing single conductors to different terminals, such as to protectors, terminal strips, or other apparatus. Either of two methods may be used in forming cables having rubber-insulated and braided conductors. In the case of rubber-insulated non-braided conductors, which are used in some pothead terminals, the taping method is generally preferable, as lacing twine may eventually cut through the insulation.

A very important part of the lacing work is carried out with lacing twine that has previously been immersed in melted wax. The appearance of a laced cable is shown in Fig. 2. The lacing should commence with a double turn at the butt of the cable and continue in single twine to the end, one tie being made at the point at which each pair or set of wires is turned from the cable. It is essential that in every tie the knot be self-binding, or the lacing will run back to the butt and the cable lose its formation. The stitches should be evenly spaced along the length of the cable.

A cable of rubber-insulated wires is usually taped. The tape is wrapped tightly, holding the group of wires in cylindrical

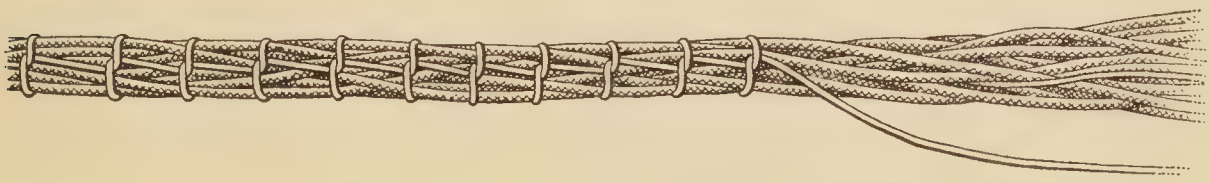

FIG. 2

shape, and with a lap of at least one-fourth the width of the tape. Where it is specially desirable to reduce the fire hazard, as in the case of a pothead terminal, a coat of fire-retarding paint is put on the completed form.

Soldering of wires to terminals is done with a soldering iron of suitable size properly pointed and well tinned. Only rosin-core solder is used for this class of work. Any other method of soldering is liable to cause corrosion.

6. Connecting Up Wires to Equipment.—If a wire is to be connected to a binding post or stud, the end should be cleaned of insulation and given about three-fourths of a turn around the binding screw in the direction in which the nut or screw tightens. The wire is not carried so far around the screw as to cross itself. If this were done, in all likelihood it would cause eventual breakage of the wire when screwed down. Usually, washers are provided on the binding post. In such cases, the wire is placed between two washers or between a washer and the body of the post. Sometimes it is necessary to have more than one wire connected to a binding post. The usual way is to place each wire under separate washers. If the bind-

ing screws are unsuitable for two wires, the wires may be soldered to one or more suitable terminal punchings.

7. Splicing.—In accordance with the specifications of telegraph and telephone companies, there should be no splicing in new installations of inside wires less than 50 feet in length.

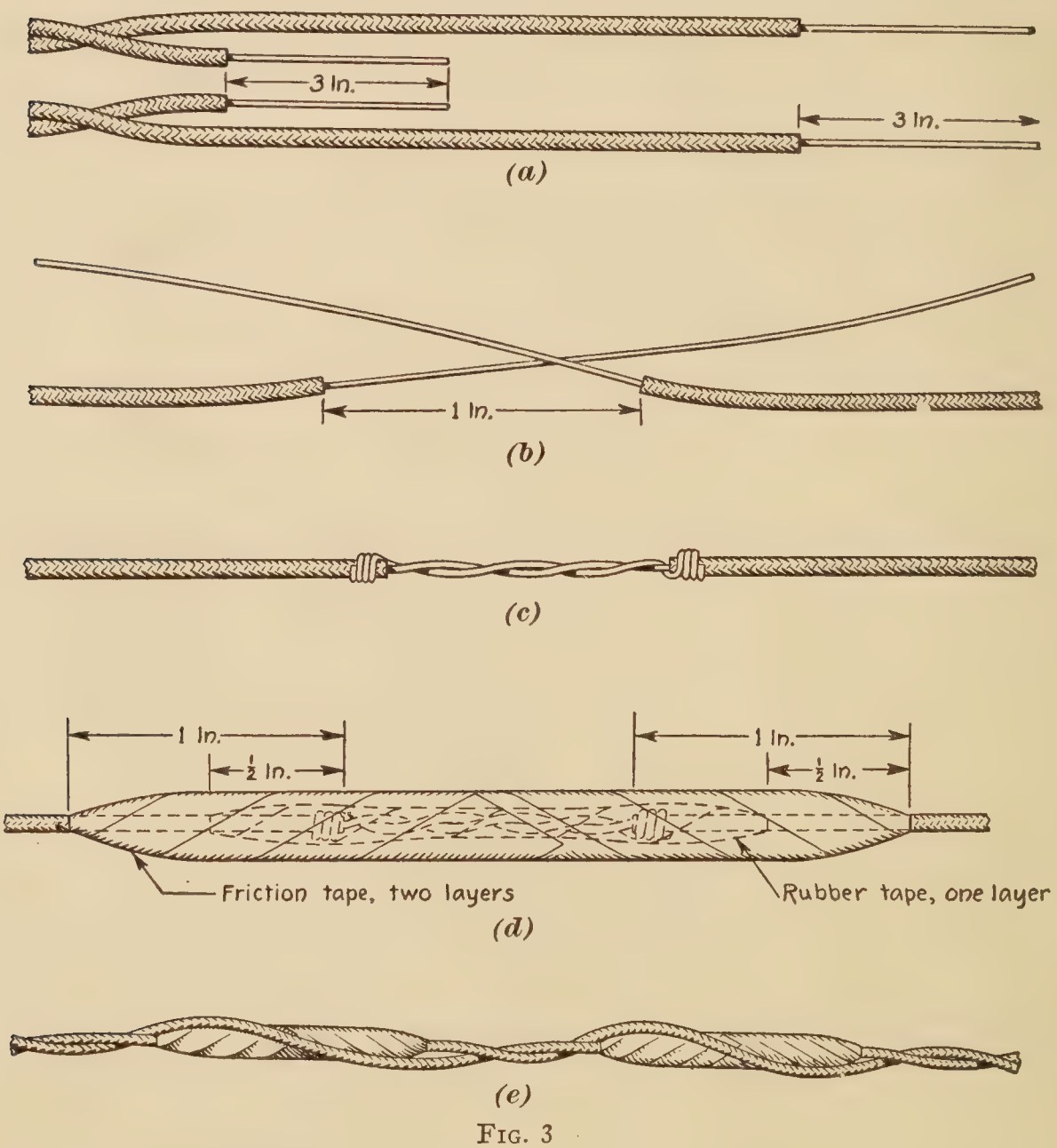

FIG. 3

In rewiring an installation because of changes in types or location of apparatus make it necessary to extend certain wires, the existing wires may be spliced when they are 20 feet or more in length and in good condition, and when existing wires are less than 20 feet in length and the conditions are such that the wires cannot be replaced without considerable labor and expense.

In Fig. 3 is shown a method of splicing twisted-pair conductors to provide staggered joints. The wires are first cut and skinned as shown at (*a*). One wire is cut off each pair 8 inches from the end. The long wire of one pair is laid over the short wire of the other pair, as shown at (*b*), and, while they are held firmly at the point of intersection, one wire is twisted three times around the other wire and the extreme ends are twisted three times around the insulation as shown at (*c*). One extra twist is given to the entire splice to insure close contact and the excess length of wire cut off. The joint is then soldered with

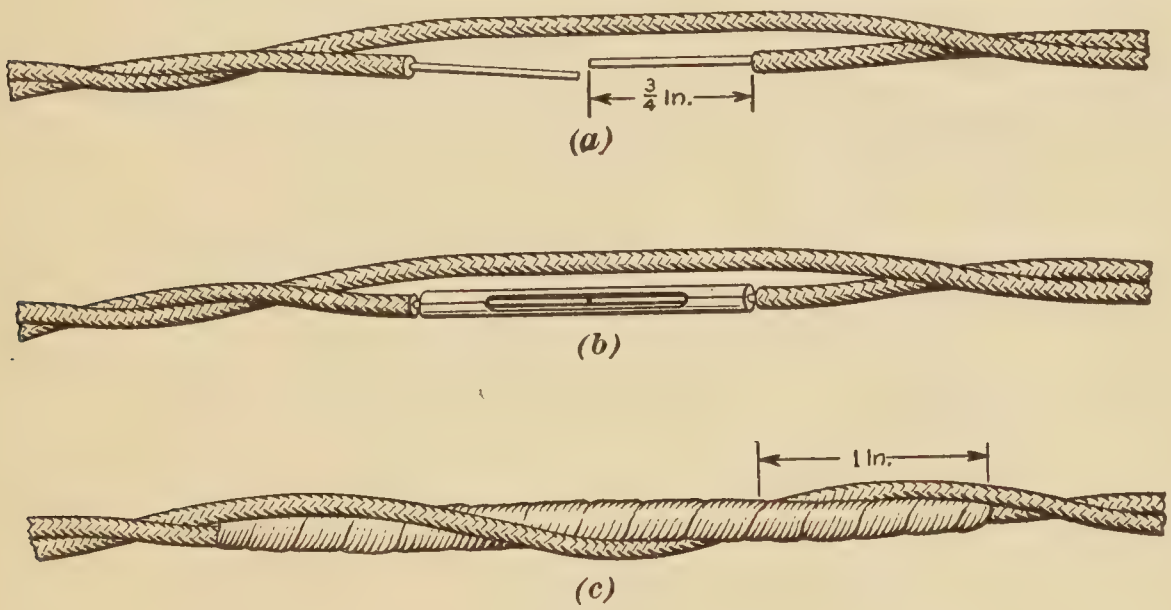

FIG. 4

rosin-core solder. For rubber-insulated wires, the joint is given one layer of rubber tape half-lapped. Then two layers of friction tape half-lapped are applied, giving the joint the appearance shown at (*d*). The second wire is spliced in the same manner, and the two are arranged as shown at (*e*).

8. Where it is necessary to repair opens in inside wires already in place, the procedure is shown in Fig. 4. Each end of wire is skinned for a distance of ¾ inch without nicking and cleaned throughout as shown at (*a*). Then, as shown at (*b*) the two ends are inserted into a tinned copper sleeve. The ends of the sleeve are pinched tightly around the wire with pliers. The entire length is then soldered with rosin-core solder.

The method of taping the foregoing joint is shown at (*c*). For rubber-insulated wires the joint is wound with one layer of

rubber tape half-lapped, then two layers of friction tape are applied half-lapped in the opposite direction. The rubber tape extends $\frac{1}{2}$ inch, and the friction tape extends 1 inch beyond each end of the joint.

TEST PANEL AND TERMINAL CABINET

9. A combination test panel and terminal cabinet generally provides a very convenient facility for testing purposes in smaller offices. In this arrangement there are housed lightning protectors or terminal strips on which the entering wires or cables are terminated. The cabinet is so located as to be readily accessible for maintenance and inspection of equipment installed within it. In many offices the cabinet is mounted on a wall or partition. In a few cases the cabinet is attached to the operating table.

In a large number of cases the test panel and cabinet are combined, as shown in Fig. 5. This is a typical arrangement for offices having not more than twenty entering wires. The outside cable enters the cabinet through a metal bushing at *a* and continues as far as the protectors *b,* where it is fanned out and the conductors connected to individual terminals. The protectors consist of line fuses and arresters.

At *c* are mounted the fuses or heat coils that protect the office instruments. The connection to the instruments is made by means of the instrument or inside cable *d*. The terminal strips are shown at *e*. Cross-connections between the different terminal blocks are made by means of jumpers, which run within the bridle rings *f*. The cable *g* forms the connection between the terminal strips *e* and jack panels *h* in the door of the cabinet.

There are cases where the combination shown in Fig. 5 cannot be made for lack of space. In that event a smaller metal box is provided for the terminal cabinet. The layout of the protectors and terminal strips, however, is identical with that of the combined unit.

INSTRUMENTS

10. The apparatus that is handled by the operators both in the actual handling of messages and for testing purposes is located in close proximity to the positions of such operators.

This is especially true in the locating of telegraph keys and sounders, relays, telephone transmitters and receivers, and so forth, together with the test panels.

A favorite method of mounting telegraph keys is to place them at an angle of either 90° or about 70° to the edge of the

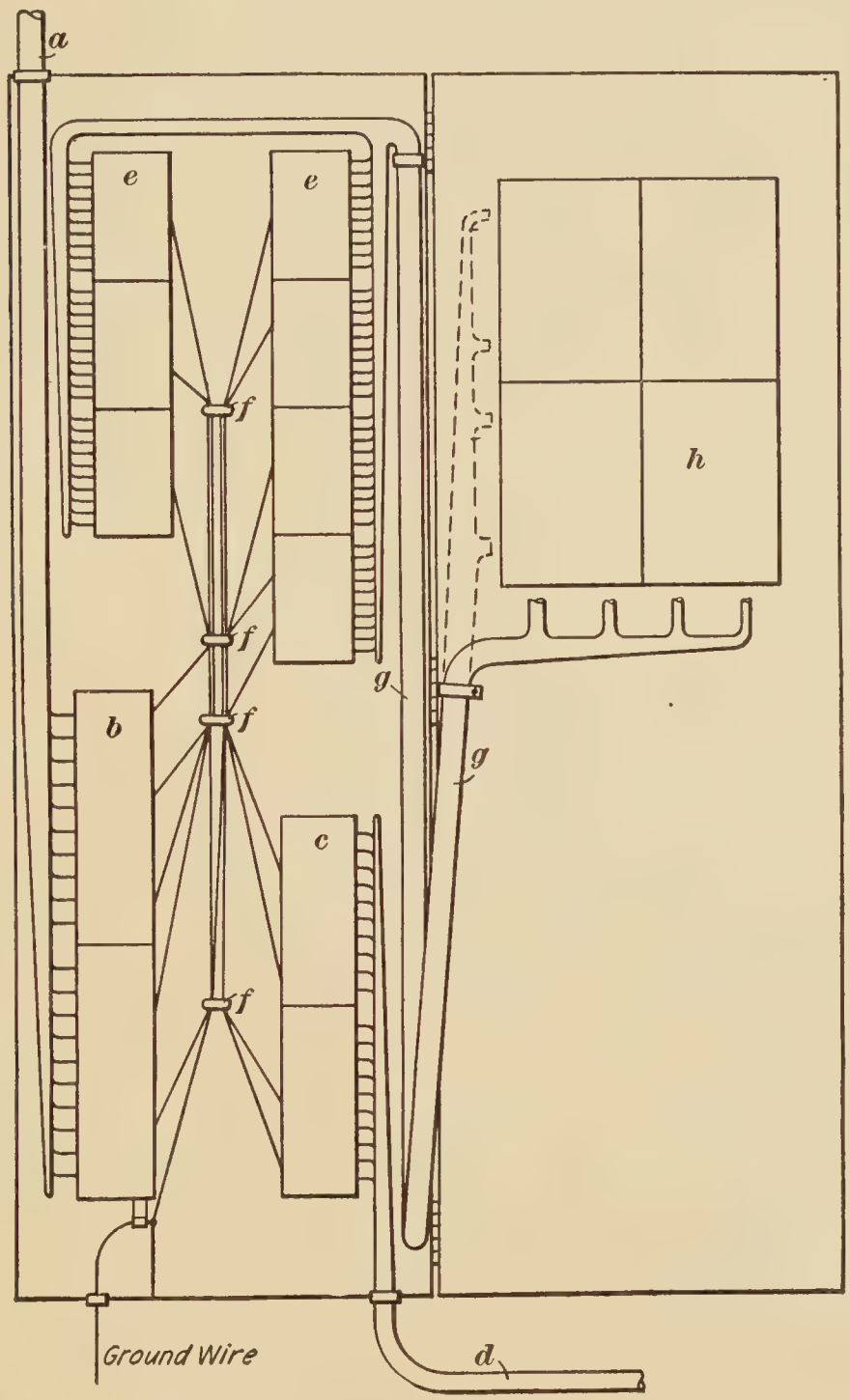

FIG. 5

operating table nearest to the operator. When the angle is 90°, the center of the key button is about 15 inches from the edge of the table. When the angle is 70°, the distance is 14 inches. In railroad offices where there are dispatchers' tables, on account

of the dimensions of the train sheet, the distance from the center of the key button of each telegraph key to the edge of the table may be increased to give proper clearance to the train sheet.

Telegraph relays are so located that they can be readily reached and adjusted. In every case it is desirable to place the relays with their coils parallel to the edge of the table in front of the operator.

Sounders are securely fastened to the table or to a resonator if one is provided. The resonators are so located as to reduce to a minimum the possiblity of sound signals being interfered with by the sound of other apparatus or exterior noises in the vicinity of the operating table.

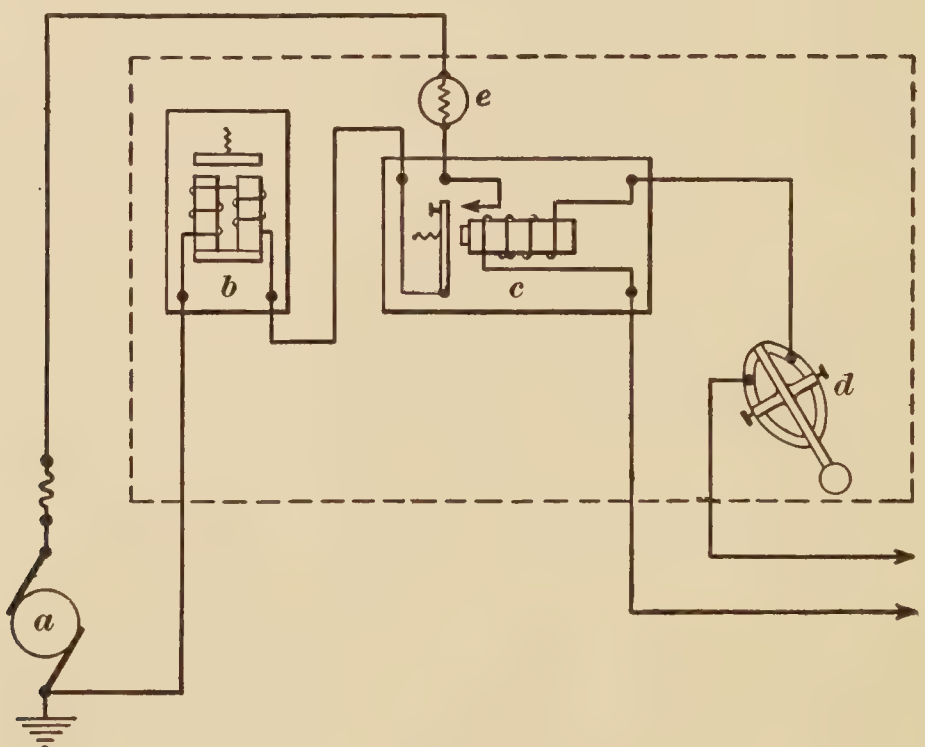

FIG. 6

11. A typical single Morse set is shown in Fig. 6. The generator or storage battery is shown at *a*, the sounder at *b*, the Morse relay at *c*, and the transmitting key at *d*. A sufficiently large resistance unit *e* must be placed in series with the generator *a* and the coils of the sounder *b* to limit the current to the safe operating value. The generator or battery voltage ranges from 12 to 160 volts. Sounders have resistance ratings of 4, 50, and 400 ohms, with a few rare intermediate values. A 4-ohm sounder requires 250 milliamperes of current; 50-ohm, 110 milliamperes; and a 400-ohm sounder, 30 milliamperes with

the coils in series, and 60 milliamperes with the coils connected in parallel. The proper resistance to use may be determined by Ohm's law.

When a telephone set is located on an operating table, the transmitter, whether mounted on a swinging or folding arm, or on a desk stand, is so located that the operator can, while using it comfortably, take a position in which his lips will be close to and directly in front of the mouthpiece.

12. When more than one telephone set is located on an operating position, the arrangement is such that there will be no likelihood of an operator's using, by chance, the receiver of one set with the transmitter of another set. Transmitter cut-out keys, or foot switches are placed within easy reach of the operator.

In offices having call-selector equipment, a cabinet is provided at an accessible location convenient for inspection and maintenance. Selector cabinets are mounted on solid walls or substantial partitions so that they are not subject to jars or vibrations from opening and closing of doors or other causes. The mounting must be such that the selector itself is level on its base.

POWER SUPPLY

13. There are still many small offices that use chemical batteries, generally for use in connection with sounder locals. In such offices suitable open shelves or boxes with glass doors are desirable because of better maintenance, enabling linemen, inspectors, and others to observe the batteries very readily. Battery shelves or boxes are so located that the cells will not be exposed to dampness or extreme variations above or below room temperature, about 70° F.

Boxes containing dry cells are so located that they will not be subject to fumes, leakage or creeping from wet cells.

The length of wiring should be as short as possible from the instruments to the battery.

14. If there is available a suitable source of current supplying power or light service, it may be utilized to advantage in

many cases. If such a source is direct current, it may be applied directly to the main-line and the local telegraph circuits through suitable resistances. It may be used also for charging storage batteries for either telegraph or telephone purposes. If the source is alternating current, it may be converted by means of motor-generators to suitable direct-current voltages. Alternating current may be converted to direct current also by means of rectifiers. Neither motor-generators nor rectifiers are suitable for direct connection to telephone transmitter circuits, and rectifiers are generally unsuited for direct connection to main-line telegraph circuits. Rectifiers when properly designed and provided with the necessary auxiliary devices for minimizing the hum, are suitable for operating selectors on telephone circuits.

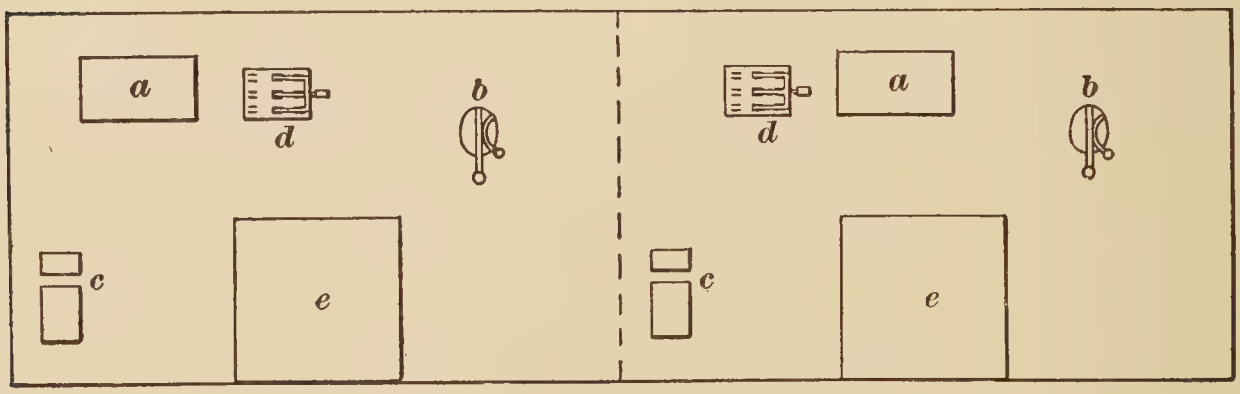

FIG. 7

It is desirable to provide connection to a suitable auxiliary reserve-current supply to assure continuity of service in the event of failure of normal supply.

MORSE DUPLEX LAYOUTS

15. In offices where the volume of traffic is such that Morse duplex telegraph operation is necessary, a special operating table is generally provided. This table permits all apparatus that comprises a duplex set to be mounted on top of the table and within convenient reach of the operator, enabling him to make the necessary adjustments for proper maintenance. In the larger offices this apparatus is mounted on a repeater table. The duplex locals are wired or looped to table positions containing only a key and a sending and receivng sounder, both the latter being usually mounted in a resonator hood.

16. In Fig. 7 a table layout for combination sets is shown. This arrangement provides positions for single-line Morse operation or for duplex operation interchangeably. Upon each position is mounted a single-line relay *a*, a telegraph key *b*, sending and receiving sounders *c*, and a triple-pole double-throw switch *d*. When the switch is thrown to the right, the position is set for duplex operation, and when turned to the left, each position of the combination set is set for single-line operation. The table provides typewriter drops *e* for both the sending and the receiving positions. The drop at the sending position on the left, enables an operator to receive as well as send at the sending position. The same is true of the receiving position on the right.

TELEGRAPH CONCENTRATION UNITS

17. Many telegraph offices have circuit operation with offices whose traffic is either normally or intermittently underloaded. These offices may be either way stations or branch offices. In order to handle such traffic efficiently in as economical and convenient a manner as possible a *concentration unit* is provided. By means of this unit one or more operators can send or receive messages from a large group of wires without moving from the table positions where they normally work.

There are two classes of concentration units. One class is arranged so that when the distant office operator opens his key, a light will be shown, indicating the wire that desires attention. When the operator at the concentration unit answers by plugging his instrument into the jack, the light is extinguished. In the second class of unit, all the distant offices call in the central office by means of a predetermined combination of long and short pulses termed a *selector call,* which operates a selector in the concentration unit and is indicated by either a light or a buzzer or both. The first class of concentration unit is generally limited to wires having only one distant office on the circuit, whereas the second class makes it possible for a way circuit having a number of offices connected therewith to have any one of such offices to call the central office by transmitting the selector call and the call will continue until the operator plugs his instrument into the answering jack.

18. The apparatus in each concentration unit comprises two groups. The first consists of telegraph relays, answering jacks, lamps, pilot relay, and selectors. The second group consists of resistances, fuses, and terminal blocks all of which are mounted in a metal box or boxes at either end or both ends of the operating table. The wire connections between the distributing frame and the operating table on which the concentration unit is located are usually made by means of lead-covered office cable or wires in conduit. The concentration unit is subject to the same wiring arrangement as applies to single-line Morse circuits coming into operating table positions. Suitable cross-connections are made at the distributing frame to complete the circuits in the concentration unit and carry the line circuits through to the switchboard for testing and patching.

19. In American practice the concentration unit has a capacity of eight circuits. A sixteen-circuit unit therefore would be the combination of two eight-circuit units. Eight-circuit units may be conveniently located on any two-position operating table. Where concentration of facilities exceeds eight circuits and is less than sixteen (two concentrator units) the concentrator may be set into a four-position table. This permits an operator occupying any one of four positions to connect his Morse set with any one of the sixteen circuits in the concentration unit. There are usually two message racks above each eight-unit concentrator. Each rack has eight compartments. These hold the messages and number sheets. Each compartment is provided with a cardholder on which is designated the particular circuit to which the compartment is assigned. The racks are within easy reach of an operator sitting at any one of the four positions.

Sometimes provision is made for transferring some of the traffic load to nearby positions. When this is done there is provided an additional table position or positions, with a key, sounder, and relay. These positions are connected with a plug and cord located in front of the concentration unit in the same way as the plugs and cords are wired to the regular positions.

MEDIUM-SIZED TELEGRAPH OFFICES

OFFICE LAYOUT

20. In Fig. 8 is shown a plan view of a typical layout of a medium-sized office having combined automatic and Morse terminal equipment as well as having repeater apparatus of different types. In Fig. 8 at *a* is shown the power-plant layout,

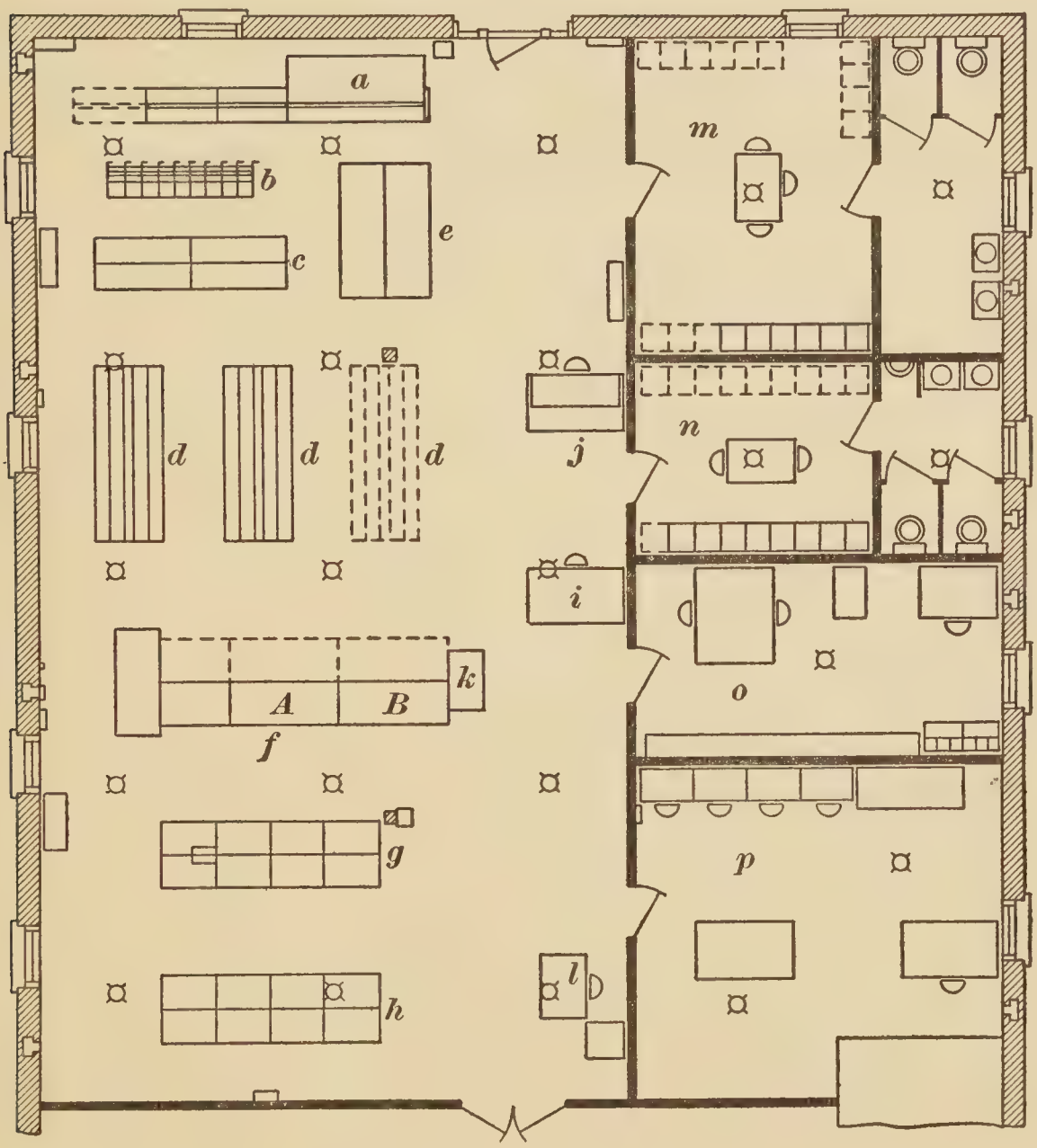

FIG. 8

which in this particular case provides current for 110-, 160-, 240-, and 320-volt potentials. The 110-volt potentials are used for supplying current for Morse locals, also for operating various local circuits in the repeater apparatus and for local operation of various units in the multiplex apparatus, and so forth.

The 160-volt potentials furnish main-line current. The 240-volt and 320-volt potentials are used for quadruplex operation. The 240-volt potentials are also used in an emergency when 160-volt potentials are not adequate at such times as heavy weather or when iron wire is substituted temporarily for copper wire. The distributing frame *b* is located conveniently behind the switchboard *c*. It is desirable to have these two units in close proximity to each other owing to the large amount of wire cross-connections between the distributing frame and the switchboard. On the standard-type repeater tables *d* are mounted universal duplex repeaters, single-line Morse repeaters, terminal Morse-duplex and quadruplex sets, time repeaters, and so forth. On the two tables *e* the rotary-type duplex repeaters are installed. These repeaters regenerate incoming signals and then pass them on automatically to the opposite line. A two-channel multiplex-circuit layout is shown at *f*. The operating channels are designated as channels *A* and *B*. Each telegram sent and received has prefixed before the message number either the letter *A* or *B*, depending on the channel in which it was transmitted. To the left of channel *A* and at the head of the row is the distributor or automatic regulating table with the artificial line arrangement for duplexing, the main-line relay, the phonic wheel motor and the tuning fork that drives it, together with the rotating brushes with the segmented face plate over which it revolves and which comprises the distributor and other associated apparatus.

21. A test table is located at the left of the distributor or regulating table *f*, Fig. 8. This table is used for testing various multiplex units locally. It is also used for feeding perforated tape into a transmitter and receiving the signals therefrom on a printer unit locally for test and observation purposes. There is also a certain amount of apparatus maintenance work done on this table.

The table *g* has single-line Morse positions. At the extreme left of this table is an eight-unit concentrator. The table *h* has a combination of single-line Morse sets and combination duplex-loop and single-line Morse positions. The chief operator's, wire chief's, and supervisor's desks are located at *i*, *j*, and *k*, respec-

tively. The message-distributing table with the pneumatic-tube table close by is shown at *l*.

Partitioned from the operating room, the women's rest, lavatory, and locker rooms are located at *m*, next to which is the men's locker and lavatory at *n*. The traffic, clerical, and file room *o* is provided with adequate space. The rear room *p* in the plan is provided for a multiplex schoolroom in which female students are trained for multiplex traffic work.

POWER PLANTS FOR TELEGRAPH OFFICES

22. Motor-Generators.—The heart of telegraph operation is in the production of power current. Not many years ago this facility was entirely dependent on gravity or bluestone batteries. In New York the main office of the Western Union Telegraph Company was equipped with over 60,000 cells of battery. These cells required a very large space, and maintenance and replacement expense was exceedingly high. A motor-generator plant taking up comparatively small floor space carried the entire load much more efficiently and economically.

Motor-generators are more economical than storage batteries under most conditions of power service. Storage batteries for telegraph purposes are most desirable in such locations where the city power is not dependable during the 24-hour period.

The standard direct-current potentials used by the Western Union Telegraph Company are as follows:

Positive	Local	Local	Local	1st	2d	3d	4th
	26 (obsolescent)	52	110	80	160	240	320
Negative				80	160	240	320

The Postal Telegraph and Cable Company use the following standard potentials:

Positive	Local	1st	2d	3d
	110	110	160	240
Negative		110	160	240

23. It is necessary to have 110-volt direct-current potentials in offices having automatic printing-telegraph apparatus to operate the local units. On some short-haul automatic trunk

circuits, 110-volt potentials are used for main-line current. If 110-volt potentials are not obtainable from city-power leads, motor-generators are provided.

As a matter of economy where city power is a direct-current three-wire system with the neutral wire permanently grounded, it is desirable to utilize this current in place of motor-generator transformation. This is done through the medium of suitable fuses located on the distributor panels. Between these fuses and the switchboard jacks or disks suitable resistances are connected.

24. Electric Power.—The kinds of commercial power currents available vary in different cities according to the system adopted by the local electric power company or companies. The several systems generally in use are as follows:

110-220-volt 2-wire direct current.
110-220-volt 3-wire direct current, neutral not grounded.
110-220-volt 3-wire direct current, neutral grounded.
240-480-volt 3-wire direct current, neutral grounded.
500-volt 2-wire direct current.
110-220-volt single-phase 60-cycle alternating current.
110-220-500-volt two-phase 60-cycle alternating current 3 wires.
110-220-500-volt two phase 60-cycle alternating current 4 wires.
110-220-500-volt three-phase 60-cycle alternating current 3 wires.
110-220-500-volt three-phase 60-cycle alternating current 4 wires.

There are a few exceptions to this listing, but they are not of sufficient importance to require special mention.

Where alternating current is furnished, it is preferable to have three-phase current. This is because the initial cost of the motors is low, the repairs small, and maximum simplicity is obtained. After three-phase current, two-phase is preferred. If neither three-phase nor two-phase is obtainable, then single-phase is used.

Alternating current is usually preferable to direct current for operating the motor ends of motor-generators. This is due to the greater stability of alternating current with fluctuating loads

on the power circuit. It is also desirable because it insures regular and constant motor speed. There will be no variation in speed, even with a variation in potential, as long as the frequency is maintained constant.

25. Reserve Power.—It is essential that all large and many smaller telegraph offices be furnished with a reserve power facility and that this facility be capable of being made quickly available. In the engineering of a reserve power plant, the first requisite is to inquire into its availability for immediate service, and the second to consider its ability to carry the entire load easily. This includes, not only the regular telegraph motor-generator load, but the motors operating the carrier systems, and the motors operating blowers and compressors for pneumatic-tube systems, and for office lighting. The economy of operation and maintenance, which, of course, should be looked into carefully, is the last consideration, the instant availability of the plant being the first. Emergency plants are generally gasoline or kerosene engines that are direct-connected to a generator that furnishes current similar to the regular current.

These plants are usually placed in the basement of the buildings where the offices are located and they must be readily accessible in cases of power failure. In a few cases emergency power is obtained from another power company in the same city or from some isolated plant by simply throwing over the main power switch to such supply.

In some cases emergency leads are provided which are used in the event of trouble with the regular leads in the power-current distribution system. This, however, is of no value in the event of power-house failure.

26. Power Leads.—It is necessary to protect properly power leads that are brought into the office and this is accomplished by providing approved switches and fuses enclosed in an approved iron box at the point of entrance. The fuses at the office end of the leads are generally of a capacity 20 per cent. greater than the fuses on the same leads at the motor-generator panel. The permissible voltage drop in leads 100 feet and over

in length is 2 per cent. when the load is taken to be the sum of the rated ampere capacity of all motors with 25 per cent. of the figure thus secured added to itself.

In Table I is shown the amperes per load under full-head conditions of direct-current and alternating-current motors. In Table II is shown the safe carrying capacity of insulated wires.

TABLE I

CURRENT IN LEADS OF MOTORS OPERATING ON FULL LOAD

Horse-power	Direct-Current Motors			Alternating-Current Motors								
				Single-Phase			Two-Phase (4-Wire)			Three Phase (3-Wire)		
	Volts			Volts			Volts			Volts		
	110	220	500	110	220	500	110	220	500	110	220	500
	Amperes in Each Lead											
1	9	4.5	2.0	14	7.	3.1	6.4	3.2	1.4	7.4	3.7	1.6
2	17	8.5	3.7	24	12.	5.3	11.	5.7	2.5	15.	6.6	2.9
3	26	13.	5.6	34	17.	7.5	16.	8.1	3.5	19.	9.3	4.1
4	33	16.5	7.2	43	21.5	10.2	21.	10.5	4.5	24.5	12.1	5.2
5	40	20.	8.8	52	26.	11.	26.	13.	5.5	30.	15.	6.4
7½	60	30.	13.	74	37.	16.	38.	19.	8.1	44.	22.	9.3
10	76	38.	17.	94	47.	21.	44.	22.	10.	50.	25.	12.
15	112	56.	25.				66.	33.	15.	76.	38.	17.
20	150	75.	33.				88.	44.	19.	102.	51.	22.

After determining from Table I how much current is to be carried by the leads, the most suitable size may be derived by the formula

$$cm = \frac{21.6\ d\ I}{e}$$

in which cm = circular mils;
d = distance, in feet;
I = current, in amperes;
e = drop in voltage.

With this result, select the size of the wire from a wire table giving the number of circular mils for each gauge.

EXAMPLE.—Determine the size of the motor leads under the following conditions:

System, 220-volt direct current.
Distance of plant from point of entrance, 150 feet.
Plant to consist of the following machines:

No. of Motors	Kind	Hp. of Each Motor	Amperes in Leads (Taken from Table I)
2	26 V. Local	2	2×8.5=17
3	1st Potential	2	3×8.5=25.5
3	2d Potential	1	3×4.5=13.5
3	3d Potential	1	3×4.5=13.5
3	4th Potential	1	3×4.5=13.5
			Total Amps. 83

SOLUTION.— $I=83\times125\%=103+$, $e=220\times20\%=4.4$ volts, permissible drop.

$$cm=\frac{21.6\times150\times103}{4.4}=75{,}845$$

Reference is made to Table II for the safe carrying capacity of wires. From the column marked Circular Mils the size of wire equal to, or next greater than 75,845 is selected, and it is noted that the wire will safely carry the total current. The wire selected in this case is 1 B. & S. gauge. Ans.

When the distance between the point of entrance and the switchboard is less than 100 feet, it is not necessary to consider the voltage drop. In such instances the full ampere rating of the plant is determined as in the former instance, and then 25 per cent. is added. From Table II, the size of wire that is listed in the column for rubber insulation to carry safely the current required is selected.

The foregoing method of determining the size of leads does not make the most economical use of copper for the theoretical loads demanded as shown, but as the acutal working load is always much below the full rating, the economical size of copper, under normal operating load, is more nearly approached. In no case are the main leads or branch leads smaller than No. 12 B. & S. gauge.

MOTOR-GENERATOR PLANTS

27. Installation.—The first item to be considered in the installation of a motor-generator plant is the foundation or support. There are generally two types; namely, reinforced-con-

crete and angle-iron frame having a bench of either slate or marble, depending on the material of which the switchboard panel consists.

It is more economical to build a concrete foundation or bench where the floors are of sufficient strength to support a heavy weight. The advantage of the concrete bench is principally

TABLE II

CARRYING CAPACITIES OF INSULATED WIRES

B. & S. Gauge Number	Circular Mills	Rubber Insulation Amperes	Other Insulations Amperes
18	1,624	3	5
16	2,583	6	10
14	4,107	15	20
12	6,530	20	25
10	10,380	25	30
8	16,510	35	50
6	26,250	50	70
5	33,100	55	80
4	41,740	70	90
3	52,630	80	100
2	66,370	90	125
1	83,690	100	150
0	105,500	125	200
00	133,100	150	225
000	167,800	175	275
0000	211,600	225	325

due to its weight, which minimizes the transmission of vibration from one machine to another. However, slate or marble benches with angle-iron frames are most generally used in the newer installations, owing to the ease of construction and good appearance. The effect of vibration of one machine upon the other is minimized by having each motor-generator rest on a sheet of thick cork.

Before beginning the concrete work in installations where concrete benches are to be installed, all floor ducts, when such are used for the accommodation of wires leading to and from the switchboard panels, are installed; at least the portions of

the ducts that are to be embedded in some part of the concrete foundation. In the latest type installations the wiring is generally placed in conduits and independent of the power bench.

In installing angle-iron frames the floor irons are properly leveled, shimming being resorted to if necessary, and firmly fastened to the floor.

28. Operation and Maintenance.—Where both polarities are used for one potential three machines are provided, mounted side by side, the central machine being the *neutral,* or alternate, machine, it being used to relieve either the first or the third machine.

In accordance with Western Union specifications, the negative machine is placed to the left and the positive to the right of the group, with the alternate machine in the center. The negative, or left-hand, machine is permanently grounded at the positive terminal and its service is connected through a single-pole switch. Likewise, the positive, or right-hand, machine is permanently grounded at its negative terminal and its opposite pole connected to the service through a single-pole switch. The alternate, or relief, machine has both poles connected to a double-pole double-throw knife switch, the connections of which are so arranged that the positive pole is grounded when the switch is thrown to the left, and the negative pole grounded when the switch is thrown to the right. The opposite pole in each case connects with the single-pole switch immediately to the left or right of the double-pole double-throw switch, according to the direction in which the latter is thrown. The top contact of each of the two last-named single-pole switches is strapped to the top contact of their adjacent single-pole switches, which control the circuits of the left- and right-hand machines. A lead from each of these straps goes to the distributing panel.

29. An attendant cannot be too careful in ascertaining whether a machine is at proper voltage before switching it in parallel to another machine. It is good practice to adjust the voltage of the machine to be cut in, a little higher than the machine carrying the load, as there will always be a drop in voltage as soon as the former machine takes its load.

Two- and three-phase alternating-current motors smaller than 5 horsepower must be started by closing the switch against the starting contacts at the bottom of the switch. The knives are to be held against these contacts until the motor comes up to regular speed, then the switch handle should be thrown quickly upwards and the knives closed against the operating and fused contacts.

SWITCHBOARD PANELS

30. Switchboard panels are erected over the motor-generator bench. The panels are made up of either Monson slate or marble free from metallic streaks and are supported by angle-iron frame work. The equipment on the face of the panel consists generally of voltmeters, ammeters, starting rheostats, and regulators for each individual motor-generator, together with the necessary switches. The indicating instruments are of small pattern of standard make and design.

All strap work back of the panels from the bus-bar to the switches is evenly and neatly taped, given several coats of shellac, and then finished with a coat of paint, preferably maroon color.

DISTRIBUTION PANEL

31. As a convenient means for distributing the generator leads to their respective services, a panel is placed at right angles and adjacent to the main row of panels. The distribution panel, besides accommodating the local office-circuit distribution fuses, also provides for the main power switch, voltmeter, and ammeter. When there is an emergency service the main switch is of the double-throw fused type and a service is brought to each side of the switch. The ammeter in a two-wire direct-current system is always connected serially in one lead, care being taken as to direction of current. The range must be such that the estimated full load comes within its full reading. For polyphase circuits an alternating-current voltmeter and ammeter are generally provided.

The distribution fuses are about 2 inches over all and are rated with a suitable margin above estimated current load of each branch lead. The fuses are arranged in groups according to voltage and polarity. The upper contacts of each group are

connected by a copper strap, and to the end contact of a group the proper potential lead is connected. The wires from the various services are brought to the distribution panel through one or more conduits, and neatly fanned into the lower connections of their respective fuses. The fanned wires are neatly taped and then given two coats of black shellac over all. This gives a glossy surface that is easy to keep clean. The length of the distribution panel is governed by the number of fuses to be provided.

LARGE OFFICES

LARGE-OFFICE LAYOUTS

32. In the consideration of the layout of a large telegraph office two viewpoints are essential; first, that of the necessities of traffic operation, involving traffic engineering study; and, second, that of plant engineering, which deals with the drawing up of plans of the office layout and the actual physical installation of equipment that is in accord with the requirements gathered as a result of traffic engineering studies. Unless these two agencies are thoroughly coordinated, inaccuracies will invariably result, causing either inconvenience or inefficiency in traffic handling, or a slowing up of the traffic speed of service in a particular office.

In a regular main operating department, the first thing to consider is the entrance by which the line wires come in from the outside. These wires come in lead-covered cables and go first to the distributing frame. The next connecting link is the switchboard and loop board, then the motor-generator or other power plant with its switchboard and fuse panels. Not far from the foregoing is the repeater department, which comprises specially designed tables on which are located Morse duplex and quadruplex sets, single-line and duplex repeaters, rotary regenerative repeaters, time repeaters, and so forth. These all comprise the *testing and regulating department.*

33. On the main floor of the operating room will be found the *automatic department,* comprising various sets of apparatus and equipment. At each circuit a terminal table is located upon which are mounted the multiplex distributor, main-line, print-

ing, and correcting relays, main-line and fork milliammeters, distributor driving fork, artificial-line apparatus, switches, fuses, resistance lamps, etc. This terminal table is located at the head of the operating channel table on which are located the printer, transmitter, and perforator units, together with the auto-control for signaling the distant end and time stamp, etc. These tables are arranged for either two-, three- or four-channel operation.

Next are found the *Morse trunk operating positions,* which are being gradually reduced in number year by year as the change from Morse to automatic operation proceeds.

The *way wires* are next in position and this includes concentration units.

In another portion of the operating room and sometimes in a separate room is the *city-line department.* Here are provided Morse operating positions at which are branch-office circuits. The method of operation in this department is destined to be changed from Morse to simplex printer circuits in a few years.

34. A very important item in the operating room is the *pneumatic-tube center.* Pneumatic tubes are concentrated in one section of the room. These tubes generally connect with the *commercial department* at the counter and delivery desks, telephone room, bookkeeping and service departments, and so forth, in the building where the operating room is located. Connection is also had with branch offices.

All messages in the operating room travel to and from one or more routing centers, where they are sorted by routing clerks and redistributed to their respective locations for further transmission or for delivery. This distribution is done through the medium of routing aides or messengers and by means of mechanical conveyers.

The *telephone department* is generally located in a separate room but as close as practicable to the main operating room, where the noise from regular telegraph operation is eliminated. In this room is the equipment for recording and delivering to customers over the public telephone and for operating the tele-

phone to such branch offices as are equipped for this method of operation. The telephone room is connected with the operating room by means of message conveyers, gravity drop or pneumatic tubes.

MECHANICAL CONVEYERS

35. There are various types of conveyers used in telegraph service. The simplest type is that of the Lamson catapult carrier, shown in Fig. 9. This consists of a suspended length of wire *a* between two stations. A car *b* with a sliding plunger *c* is suspended from the wire by means of two grooved wheels *d*.

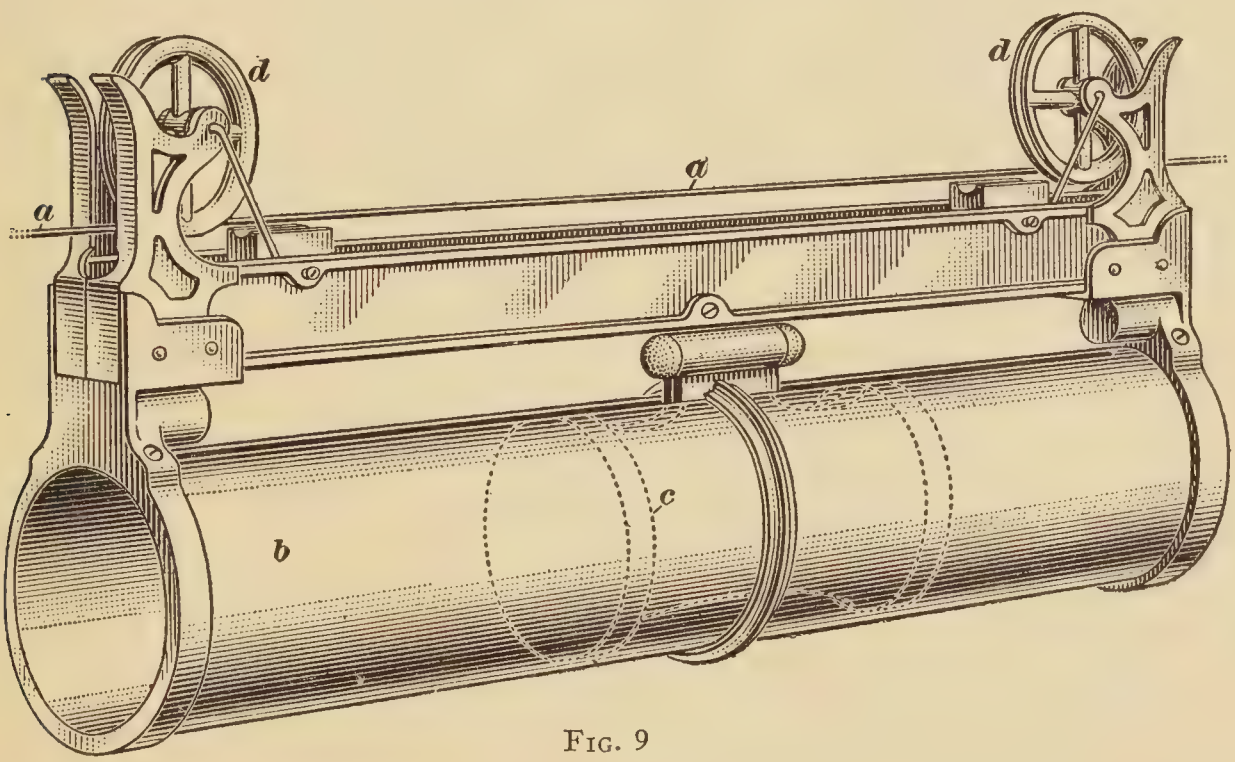

FIG. 9

The car *b* is of the tubular type having a diameter of about 2 inches. The messages are rolled up and placed inside a cylindrical carrier. When the carrier is forced to the other end the messages are thrown out by the impact and the loose sliding plunger *c* inside the carrier. The carrier operates in a similar manner in either direction.

There are several methods of forcing the carrier forward from the sending station. One of these is shown in Fig. 10 in which a stout elastic cord *a* is first stretched and then suddenly released by the pulling of a cord *b*. This sends the carrier *c* to the opposite station, where it is caught by the impact of the elastic cord and held by the latch trip *d*, which prevents it from rebounding. This same latch trip *d* is released when the pull

cord is pulled, which stretches the elastic cord and finally releases the latch trip, forcing the carrier to return to the opposite station. In this case the carrier *c* is of the clip type, in which the messages are held by the message clip. This latter clip has a limited use in telegraph offices.

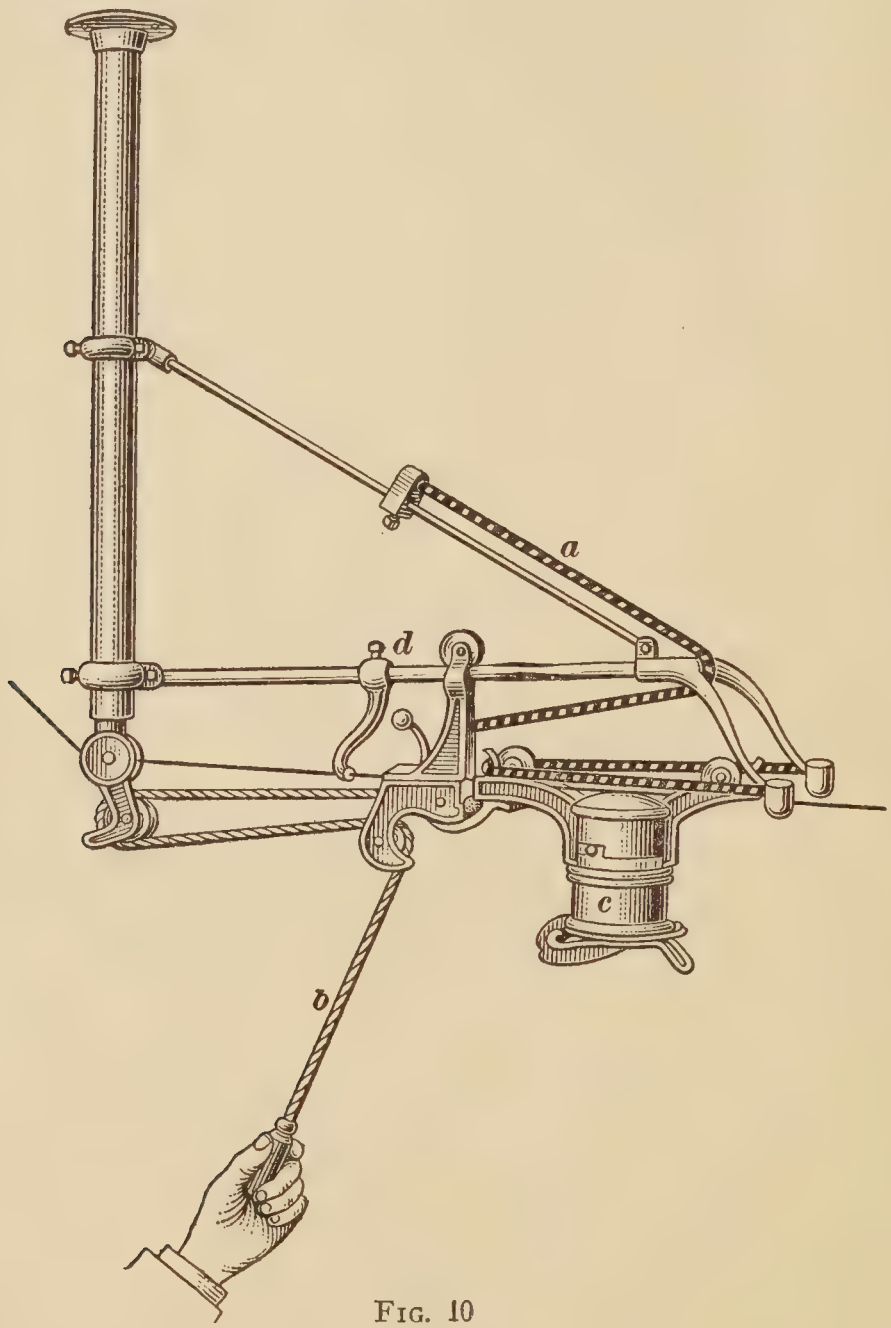

Fig. 10

36. Another catapult method of forcing a carrier forward is shown in Fig. 11. In this arrangement coiled springs are located inside a tube *a* and when the pull cord *b* is jerked quickly the spring is first compressed and finally released, impelling the carrier forward. The rebound is prevented by a friction tube *c*, which is slipped over the track wire at each station. The carrier is cushioned in its incoming impact by a cord *d* directly in front of the carrier support.

Another type of catapult carrier, which is much used in the telegraph service, is that known as the *kickback carrier*. This arrangement requires two separate lines, one for sending and

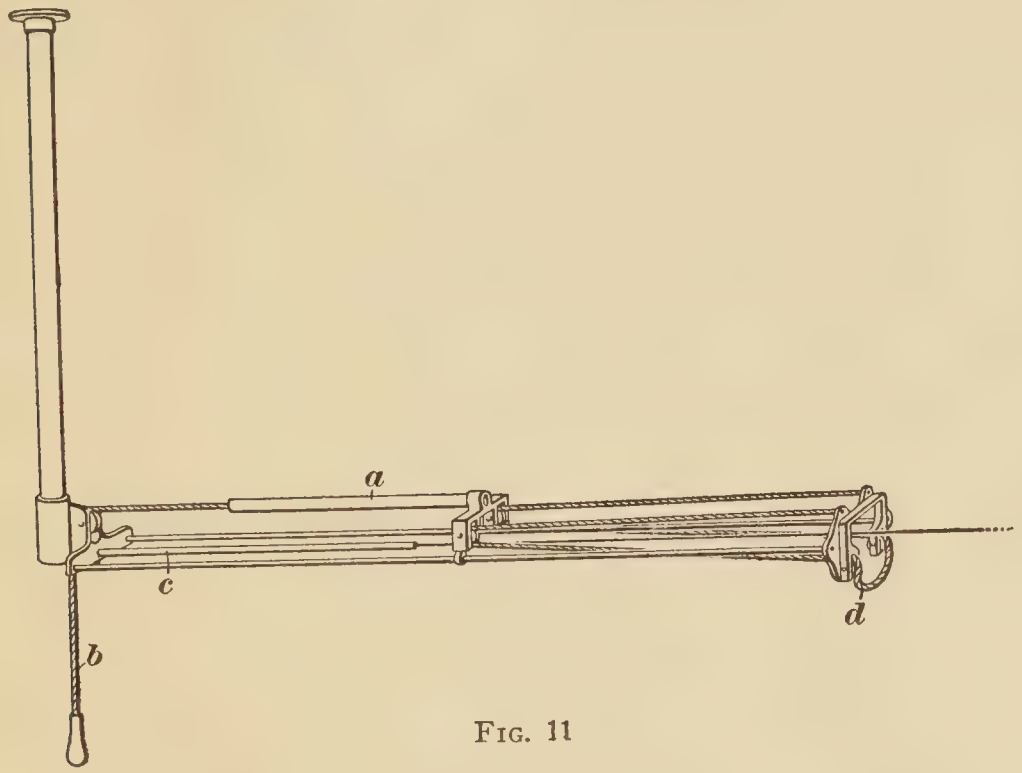

FIG. 11

one for receiving, because the carrier will convey traffic in only one direction. The carrier is propelled from the sending station in the manner already described and strikes the receiving cushion abruptly. The impact thus made causes the carrier to discharge its contents automatically into a specially designed chute,

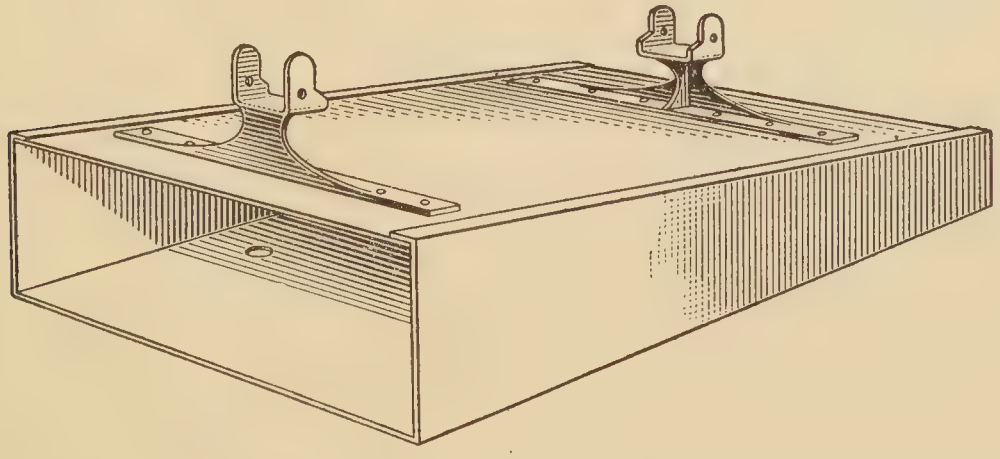

FIG. 12

or *drop*. The impact of the carrier stretches the rubber cord or coiled spring, creating sufficient tension to force the carrier back to the sending station ready for the next operation.

37. The car used in connection with the kickback carrier is that known as the rectangular type and is shown in Fig. 12. The front end has a somewhat wider opening than the opposite end, which enables messages to be discharged with greater facility into the chute, or drop, when the carrier is suddenly halted at the discharging point.

As a general rule, the catapult carriers are used only in small or medium-sized offices. In the large telegraph offices other conveyer systems of a more substantial character are employed.

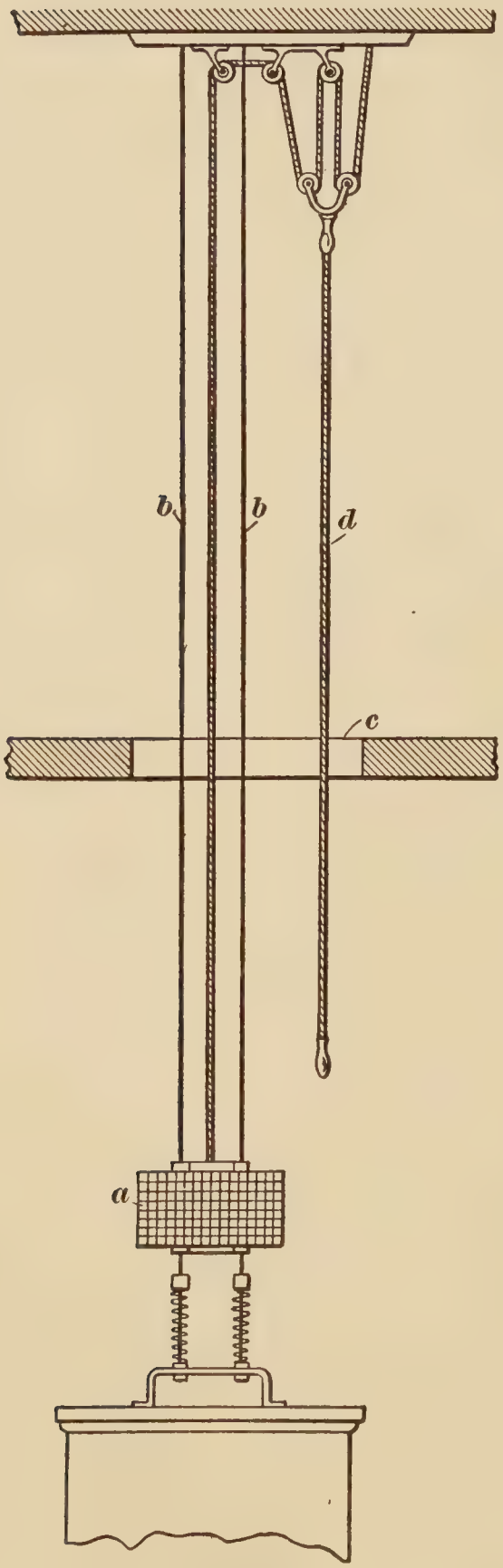

FIG. 13

ELEVATOR CARRIERS

38. Some telegraph offices require a method whereby messages can be lifted upwards from one floor to the floor above. This is often used where the commercial department is located on the ground floor and the operating room on the floor above. In such cases an *elevator carrier,* Fig. 13, is employed. The elevator carrier is generally in the form of a flat basket *a*. It travels between two guide wires *b* and is lifted from the lower to the upper floor through an opening *c* in the floor. The pulling cord *d* has a 4 to 1 lifting pull through the arrangement of the pulleys. This enables the car to travel much faster than would be possible with the straight-pulley method.

LAMSON SELECTIVE CARRIER SYSTEM

39. An ingenious system of selective carriers is that devised by the Lamson Company, which has been used by telegraph companies for many years. With this system a carrier will simultaneously deliver and pick up messages at a selected station, and will pass over other stations that are adjusted for other carriers. As many as eight of these carriers can be located on one line of approximately 200 feet in length. A carrier as it is passing a station is shown in Fig. 14. The carrier *a* travels

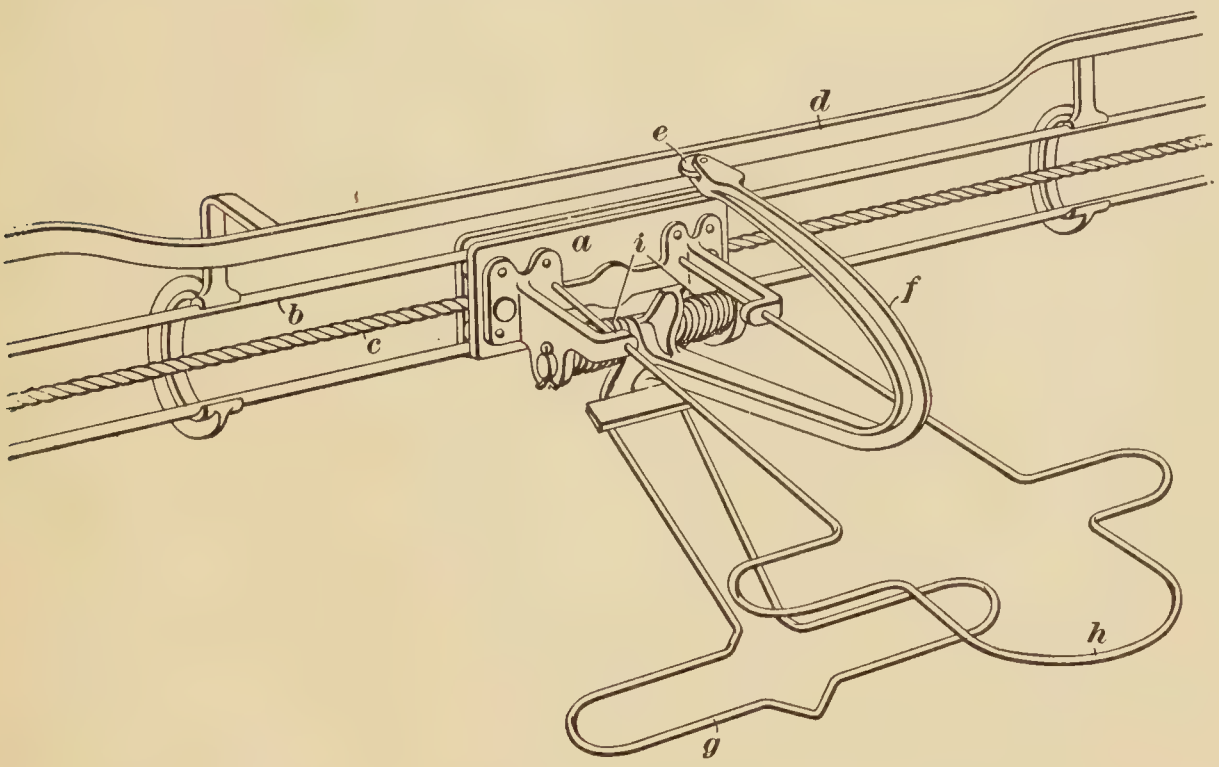

FIG. 14

on a suspended track *b*, one rail above the other, and is drawn along by the cable *c*. A guide frame, or cam, *d* is shown upon which the roller *e* of the cam arm *f* travels while the carrier *a* is passing the selected station. Attached to one end of the cam arm *f* is a movable jaw *g*, which normally presses against the fixed jaw *h*. The messages are held between the fixed and movable jaws. The movable jaw *g* is separated from the fixed jaw *h* by the action of the arm *f* when operated by the cam *d*. When the jaws *g* and *h* separate, at the selected station, the messages drop by gravity into a metal pan. After the carrier *a* passes the limits of the cam *d*, the movable jaw *g* is forced against the fixed jaw *h* by the springs *i*. Each of the carriers *a*

of a system has one cam arm *f* of such length as to make contact with a cam *d* located at a definite distance from the track. Another carrier will be affected by another cam at another distance from the track. This enables carriers traveling on the same track *b* to pick up and deliver messages at the desired stations.

40. A combination sending and receiving station is shown in Fig. 15. In the system shown, there are three cams *a*

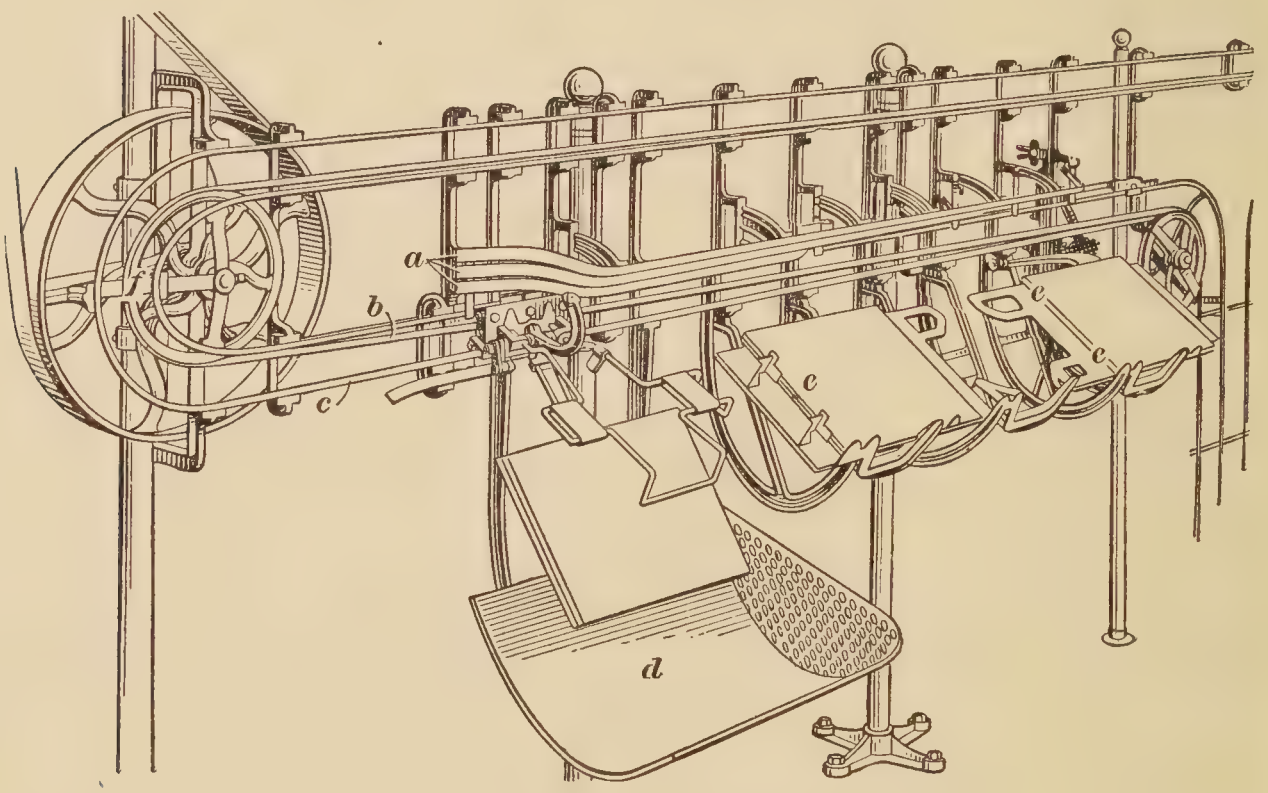

FIG. 15

to operate three types of carriers. The cable *b* pulls the carriers along the track *c*. When a carrier moves toward the right and the roller on the end of the cam-arm comes in contact with a cam *a,* the jaws open and drop the messages they may have collected, into a receiving pan *d*. As long as the cam *a* is active the jaws remain open. The messages to be sent are placed on a dispatching shelf *e*. There is one shelf for each of the stations on the line. The open jaws pass by the messages, one above the shelf and the other below; but one of the three types of carrier closes its jaws when the carrier is at the center of its particular position, because at this point the roller of the cam-arm loses contact with the cam. When the jaws close, the movable jaw passes through an opening in the shelf *e* and the

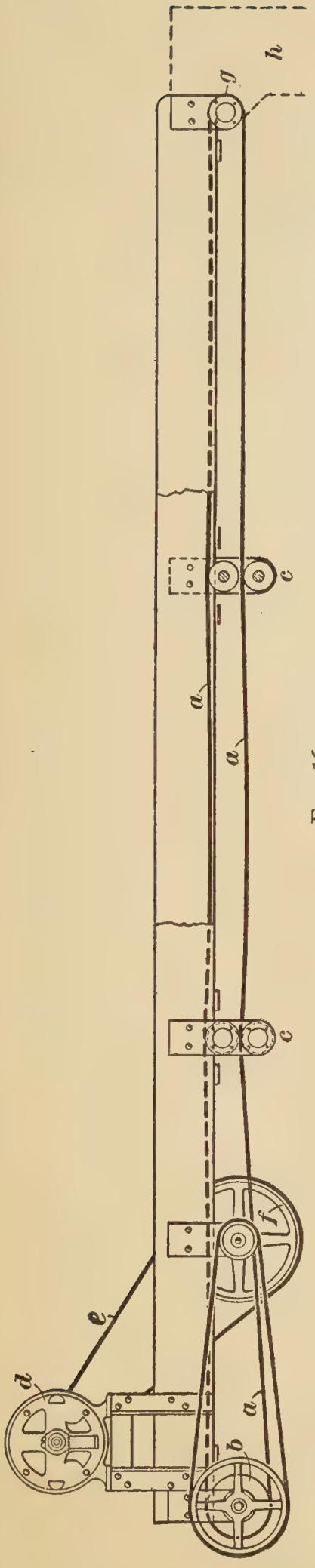

FIG. 16

messages are clamped between the jaws and travel to their selected station. The cable *b* is looped around a grooved pulley *f*, which in turn is driven by an electric motor.

BELT CONVEYER

41. The catapult and Lamson selective carriers have a somewhat limited application in the larger offices, where there is a large volume of traffic that must move with a maximum speed. For this reason a more comprehensive and expeditious conveyer must be provided. To attain this end the belt conveyer system shown in Fig. 16 has been utilized. This system consists of an endless moving belt *a* situated in a channeled space. The belt is made up of a cotton weave about 11 inches wide, which is slightly more than the width of a regular telegraph blank. The belt is driven through the medium of an end roller *b*. The belt is supported by idler rollers *c*.

The motor *d*, which drives the belt *a*, is mounted on a platform above the channel guides. The drive is by means of the belt *e*, which operates the drive wheel and pulley *f*, and pulley *f* in turn, by means of a belt and pulley, drives the end roller, or drum *b*. At the opposite end of the belt is the end roller *g*, at which point the messages are discharged into a chute *h*. This chute is made of sheet iron and is perforated so that messages that fall

inside the chute can be readily observed. The bearings are mostly ball bearing to reduce friction. In some places, as in telephone rooms, the bearings are in felt to minimize noise or vibration. One idler roller is of smaller dimensions as compared with the opposite roller. This is to permit proper clearance for the carrying rollers at the top portion of the belt.

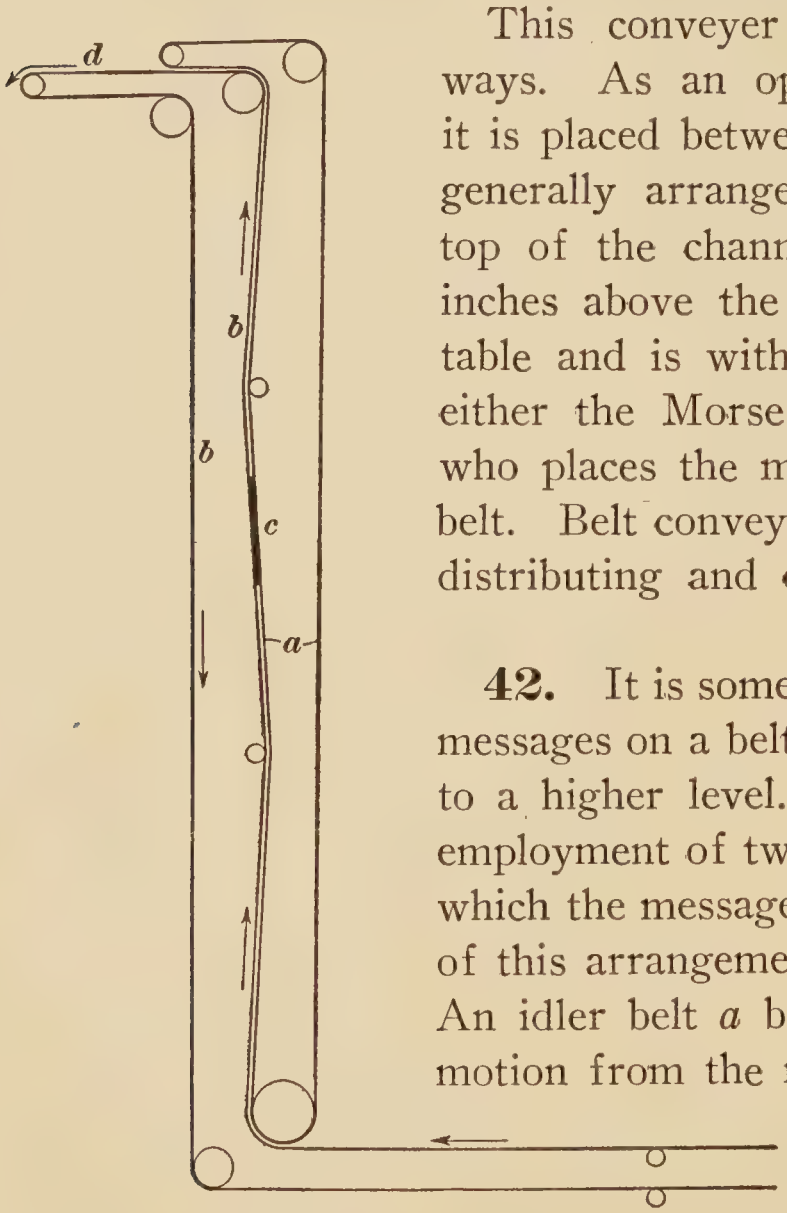

FIG. 17

This conveyer is applied in various ways. As an operating table conveyer it is placed between two operating tables generally arranged back to back. The top of the channel guide is usually 23 inches above the level of the operating table and is within convenient reach of either the Morse or automatic operator who places the messages on the moving belt. Belt conveyers are also used at the distributing and delivery centers.

42. It is sometimes necessary to raise messages on a belt conveyer from a lower to a higher level. This necessitates the employment of two vertical belts between which the messages are held. A diagram of this arrangement is shown in Fig. 17. An idler belt *a* bears on and derives its motion from the main belt *b*. The messages are held between the idler and main belt. A message blank *c* is between the belts *a* and *b* and on its way to the discharging point *d*. The figure shows a space between the idler and main belts for the purpose of better illustration. Actually, however, the belts are close together to hold the messages better on their upward journey.

PNEUMATIC TUBES

43. Use of Pneumatic Tubes.—Another means of mechanical communication used in telegraph offices is that of pneumatic tubes. This system permits the actual physical transmission of messages through a tube for short distances on a very economical basis. Pneumatic tubes are used extensively for interdepartmental communication, generally in one building, and are

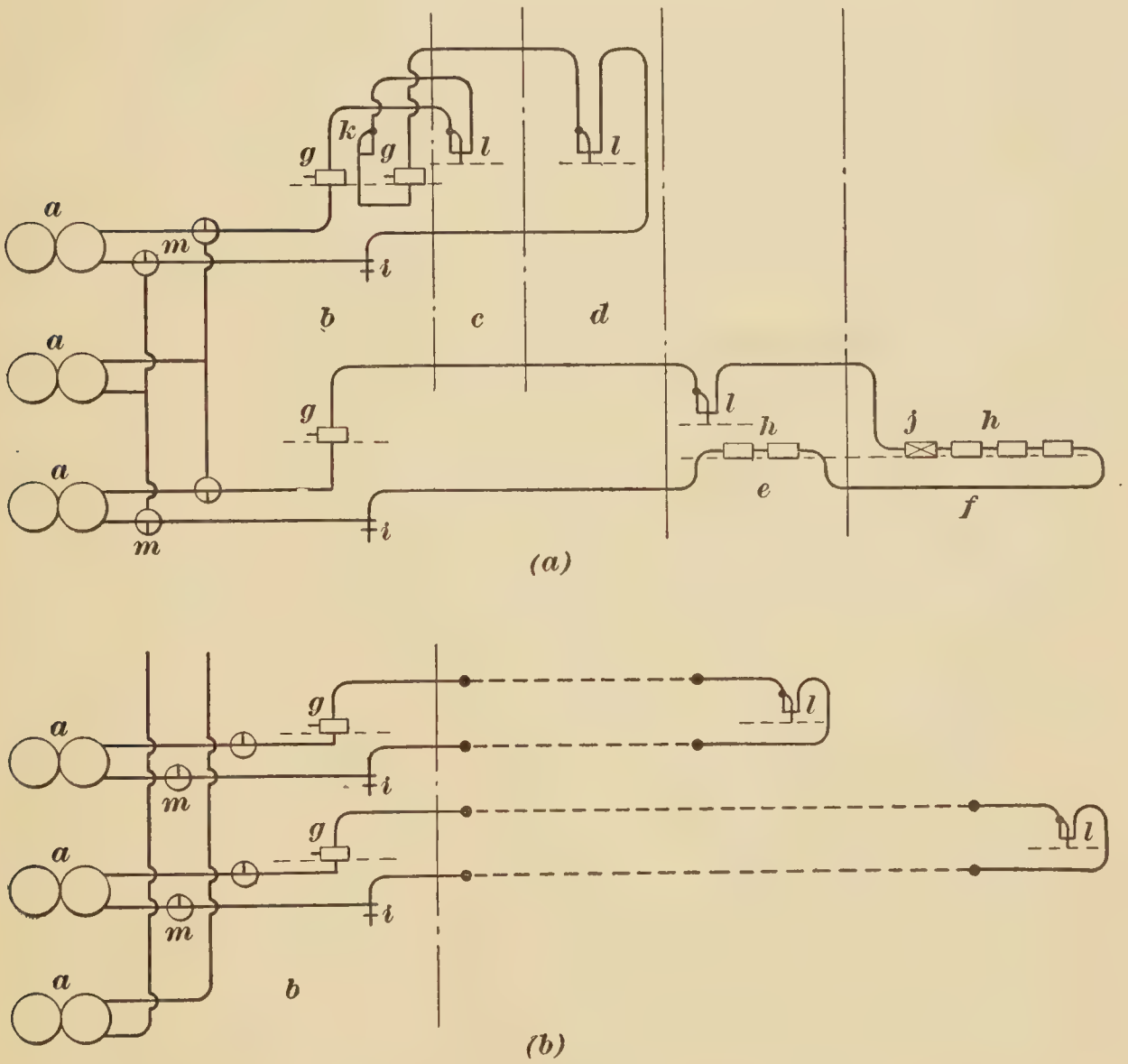

FIG. 18

known as house tubes in contradistinction to outside or street tubes.

44. Pneumatic-Tube System.—A schematic layout of a typical pneumatic tube system is shown in Fig. 18. View (*a*) shows a house-tube system and view (*b*), a branch-office system. The system consists essentially of a number of blowers *a*

that provide air pressure and suction to a series of tubes with suitable sending inlets and receiving terminals. The carriers bearing the messages are forced by air pressure through the tubes.

The house-tube system, view (*a*), has one series of tubes extending from the operating room *b* through the testing and regulating department *c* to the phone room *d*. The other tube extends from the operating room to the delivery counter *e* and to the customers' counter *f*.

The branch-office system, view (*b*), has direct tubes between the operating room *b* and the individual branch offices. The sections indicated in broken lines are removable.

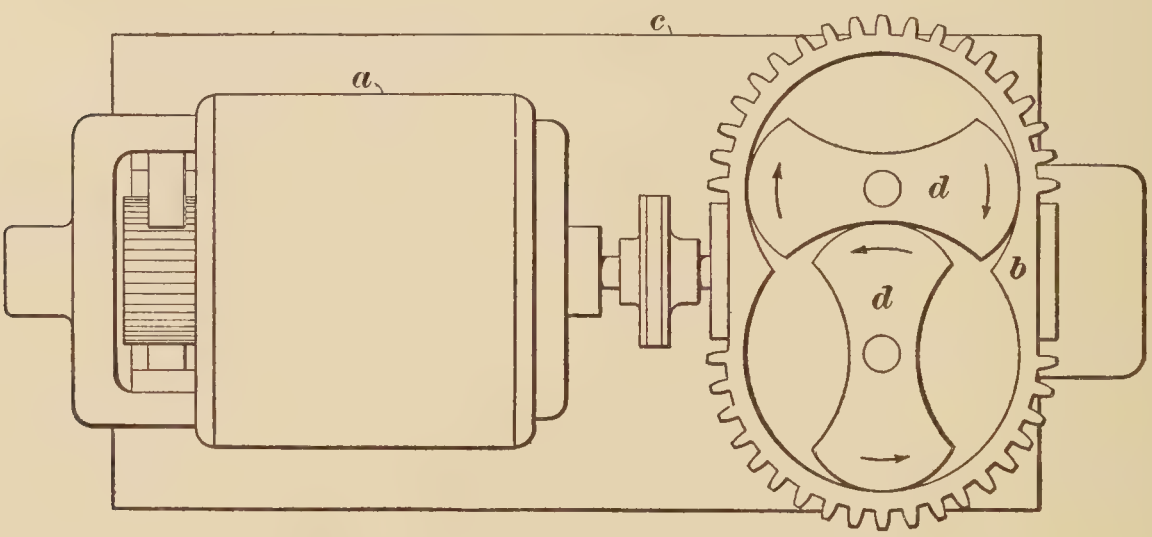

FIG. 19

The symbols *g* and *h*, Fig. 18, represent two types of sending inlets, and the symbols *i*, *j*, and *k* represent three types of receiving terminals. Combination sending inlets and receiving terminals are indicated at *l*. At *m* are indicated the three-way switching devices. Some of the devices will be considered in detail.

45. Needham Blower.—One of the types of motor blowers used for pneumatic tubes in the telegraph service is that of the Pneumatic Tube Supply Company, and known as the Needham Blower. In Fig. 19 is shown a top view of this type of blower. It consists of an electric motor *a* and blower *b* mounted on a common base *c* and coupled together as shown. The blower casing or body is made up of cast iron with cooling fans to insure fairly cool running. The delivery of air by the blower

is effected by causing two impellers *d* to rotate in opposite directions at a speed of about 300 revolutions per minute. These impellers are each driven by a worm gear mounted on the impeller shaft and actuated by a worm keyed to the main shaft. The impellers *d* are kept in alinement by means of two helical gears of equal pitch which are also keyed to the impeller shaft directly below the worm gears.

With the motor turning in a clockwise direction, the observer looking toward the commutator, the impellers *d* will turn in the direction indicated by the arrows. The air will then enter on

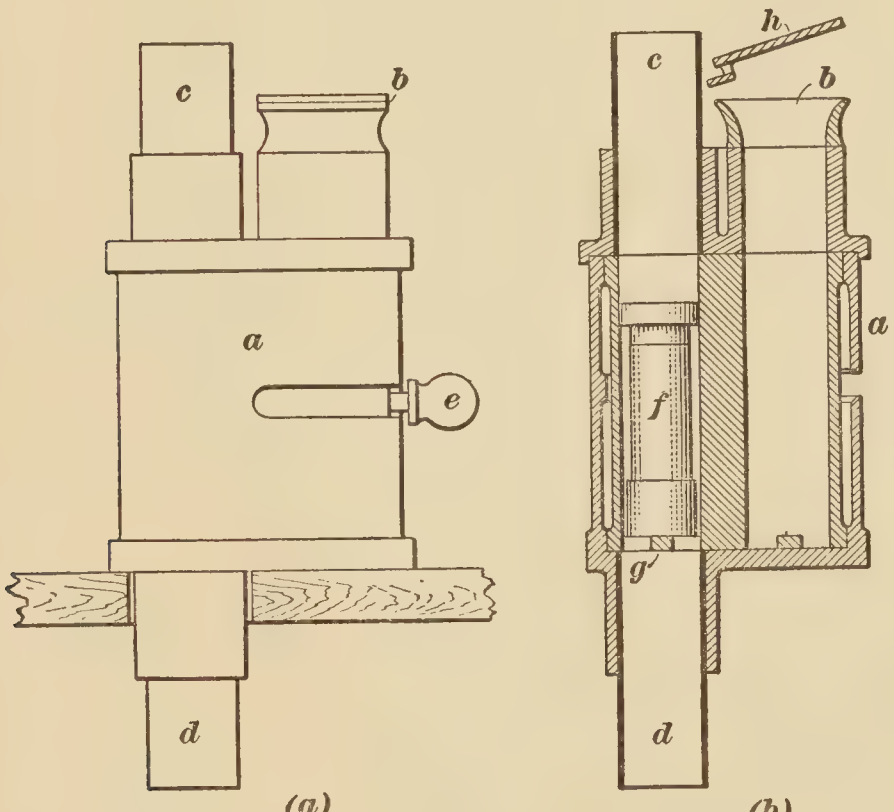

FIG. 20

the motor side, which is known as the *vacuum* side, and discharge on the opposite side of the blower, which is called the pressure side.

The driving mechanism is located at the bottom of the casing or body in a separate compartment from the vacuum and compression chambers. The air space between the upper chambers and the driving casing is utilized by the center bearing assembly and keeps lubricating oil, which is in the lower casing, from working up into the upper air chambers.

46. Radial Sending Inlet.—The radial type of sending inlet indicated at *g*, Fig. 18, is shown in Fig. 20. As indicated

in view (*a*), this type of inlet consists of a cylindrical casting *a* with an opening *b* on top to receive carriers to be dispatched. There is also an opening *c* for a tube-line connection. An opening *d* on the bottom directly below the tube-line opening on the cover, serves as the air-pipe connection from the blower.

A rotor contained within the casting *a* serves to receive the carrier from the opening *b*. When the rotor is rotated 180° by means of the handle *e*, it places the carrier *f*, view (*b*), in the tube line through which the air is circulating and which propels the carrier to its destination. The carrier *f* is a small fiber tube that fits snugly within the air pipe.

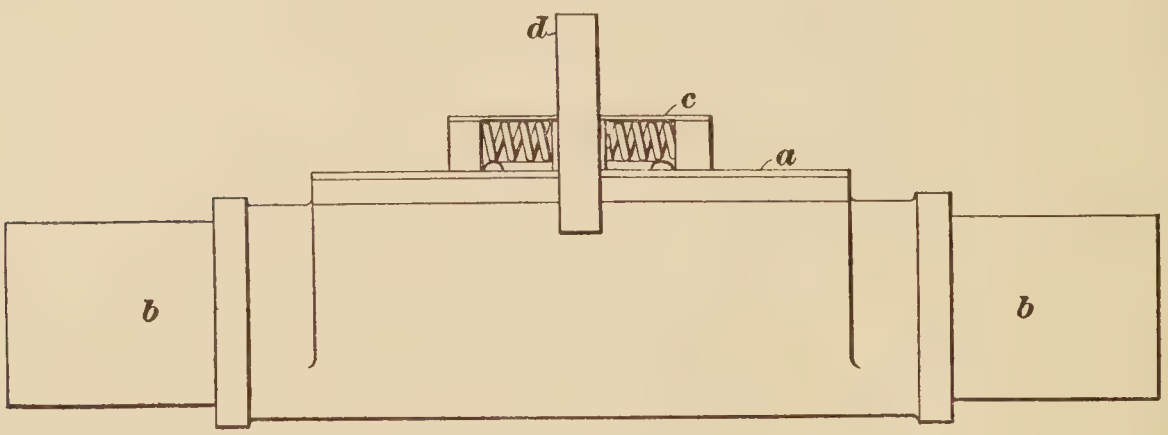

FIG. 21

The radial sending inlet shown in Fig. 20 is installed at the beginning of the pressure line. If inlets are to be installed at intermediate points for through sending, the bridge *g* at the bottom of the inlet chamber is removed. The inlet mouth cover *h* for the radial type of sending inlet may be locked in place when the inlet is not in service.

47. Side-Door Sending Inlet.—The side-door sending inlet indicated at *h*, Fig. 18, is shown in Fig. 21. It is a box-type casting equipped with a door *a* to allow inserting carriers in the tube *b*. The door is kept normally closed and air-tight by the force of the spring *c* and latch *d*.

Side-door sending inlets are installed directly in the air line and are particularly adapted for installation under a blind counter or flush with counter tops and may be installed horizontally or vertically. They are installed at intermediate points, preferably on the vacuum side of the line.

48. Stirrup Sending Inlet.—The stirrup sending inlet consists of a brass case with stirrup-type door for insertion of carriers. It is equipped with motor-starting contacts. The inlet is designed for use at intermediate points and cannot be used for through sending.

49. Double-Valve Receiving Terminal.—The double-valve receiving terminal, shown in Fig. 22, is an automatic discharge

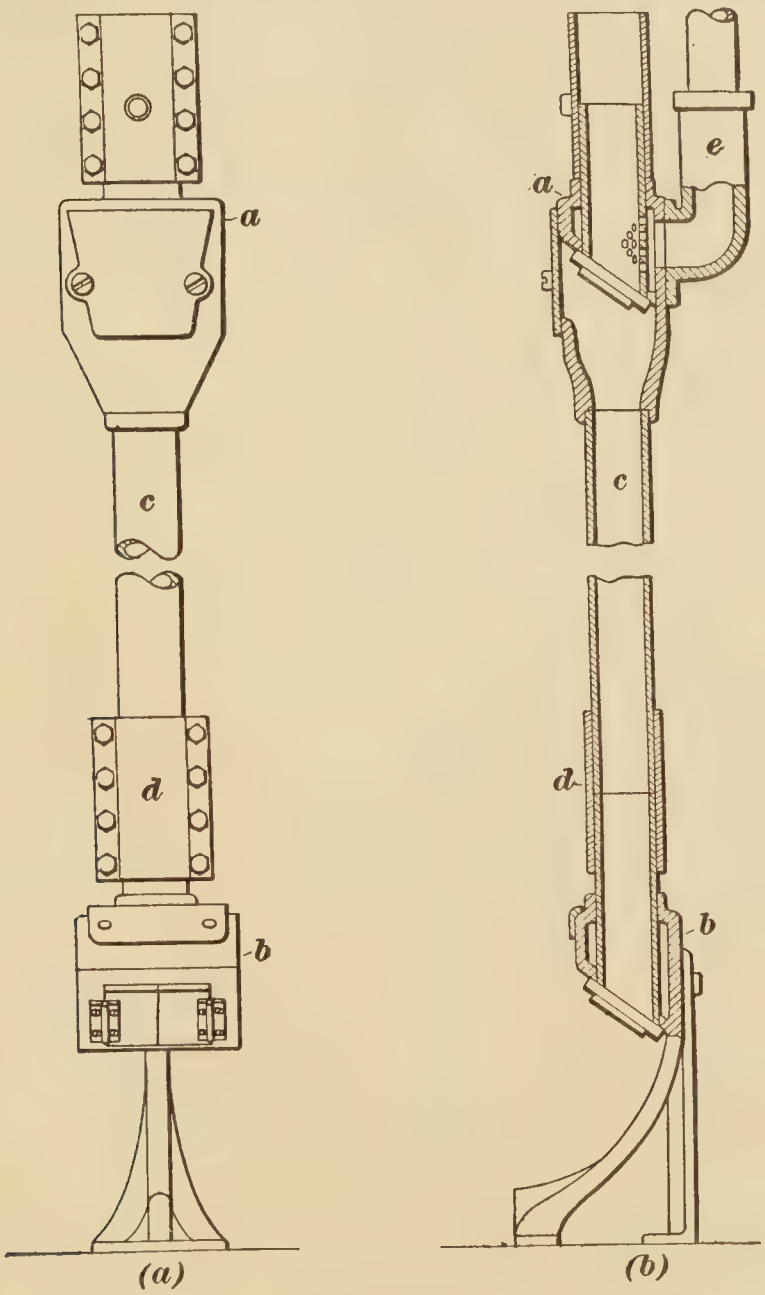

FIG. 22

device. View (*a*) is the front view of the terminal and view (*b*) a side section. The terminal consists of two valves *a* and *b*, views (*a*) and (*b*), with balanced hinged doors separated by a piece of steel sleeving *c* and a cast split sleeve *d*. The upper valve *a* is fitted with the air by-pass *e*, view (*b*).

The lower valve *b* may be termed the check-valve in that it checks the upward rush of air to the by-pass *e* when a carrier opens the upper valve *a*. The terminal near valve *b* is generally used as the receiving terminal at either the vacuum or the blower end of the tube line.

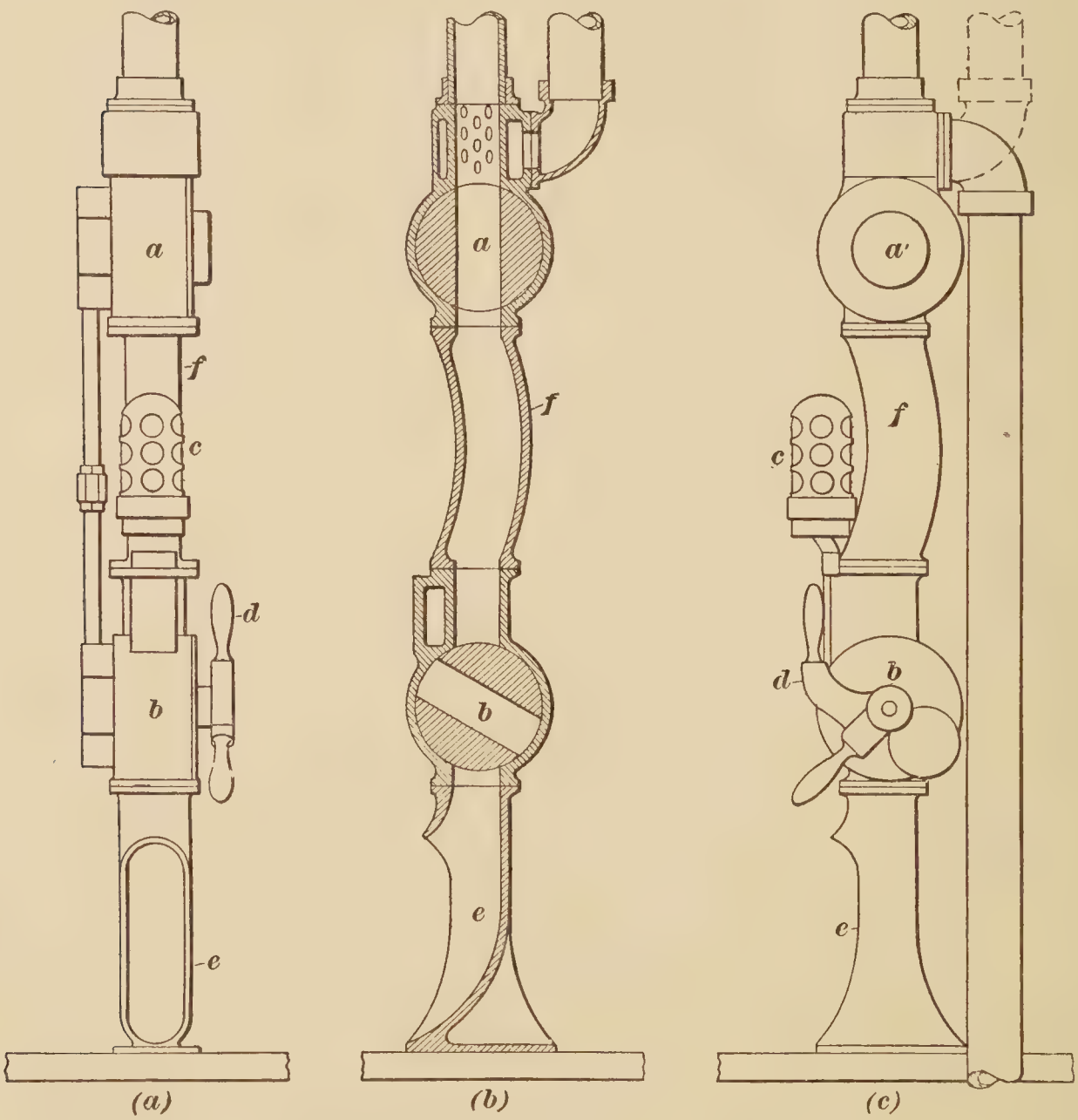

FIG. 23

Careful maintenance is necessary with this type of terminal, as the valve hinges, which constantly receive the pounding of the carriers, wear rather rapidly. Eventually they become loose, the result being air leaks, which tend to make the terminal inoperative.

50. High-Pressure Receiving Terminal.—The high-pressure receiving terminal shown in Fig. 23 has been developed to

allow its installation at intermediate receiving points on the pressure side of the line without losing any air, as would be the case with some of the other types of receiving terminals. This is made possible by the use of simultaneously operated cylindrical valves *a* and *b*, views (*a*), (*b*), and (*c*), which are machined tight to prevent air leaks. When the valves are in normal position, the upper valve *a* is open and the lower valve *b* is closed. The air is by-passed above the upper valve.

When a carrier has passed through the upper valve and has come to rest on the lower one, contacts are closed, actuating a signal light *c*. The attendant then turns down the handle *d*, which closes the upper valve *a* and opens the lower valve *b*, permitting the carrier to drop out through the chute *e*. The slight curve in the tube *f* reduces the speed of the carrier.

In the event of the piling up of carriers, which would prevent the closing of the upper valve, the handle *d* is turned upwards to the rear, which only actuates the lower valve, opening it. This causes the carriers to be blown out, after which the handle is moved in the normal position again.

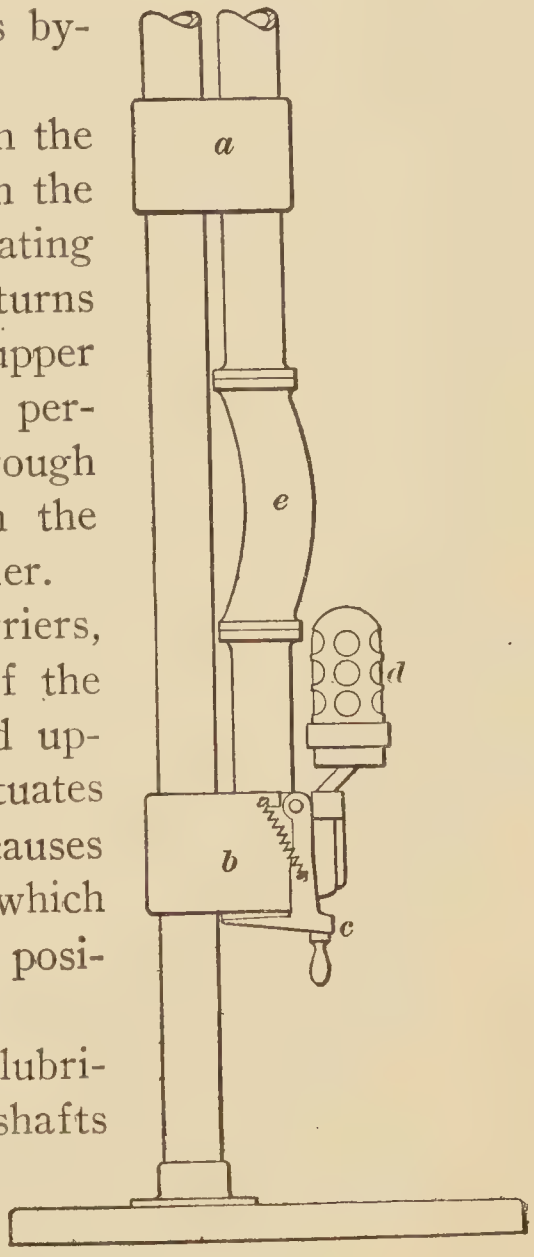

FIG. 24

Attention should be given to the lubrication of this terminal, as the valve shafts rotate on ball bearings, and a drop of oil occasionally on the valve rotor is necessary not only from the standpoint of lubrication but in that it aids in making the valve air-tight.

51. Stirrup Receiving Terminal.—The stirrup receiving terminal is shown in Fig. 24. A by-pass *a* is located 3 feet 6 inches above the stirrup casting *b*. This terminal is equipped with a stirrup door *c*, signal-light contacts, signal lamp *d*, and

speed breaker *e*. This terminal is for installation at intermediate points only, where an air-tight terminal is not required, as in house tubes, and is not recommended for use at the blower end of a vacuum line.

52. Combination Stirrup Terminal.—The combination stirrup terminal is a combination of the stirrup sending inlet and stirrup receiving terminal, with a body casting to hold the receiving stirrup, the sending stirrup, and a by-pass tube from the by-pass, which is located 3 feet 6 inches above the body casting on the receiving terminal. In appearance it resembles the stirrup receiving terminal.

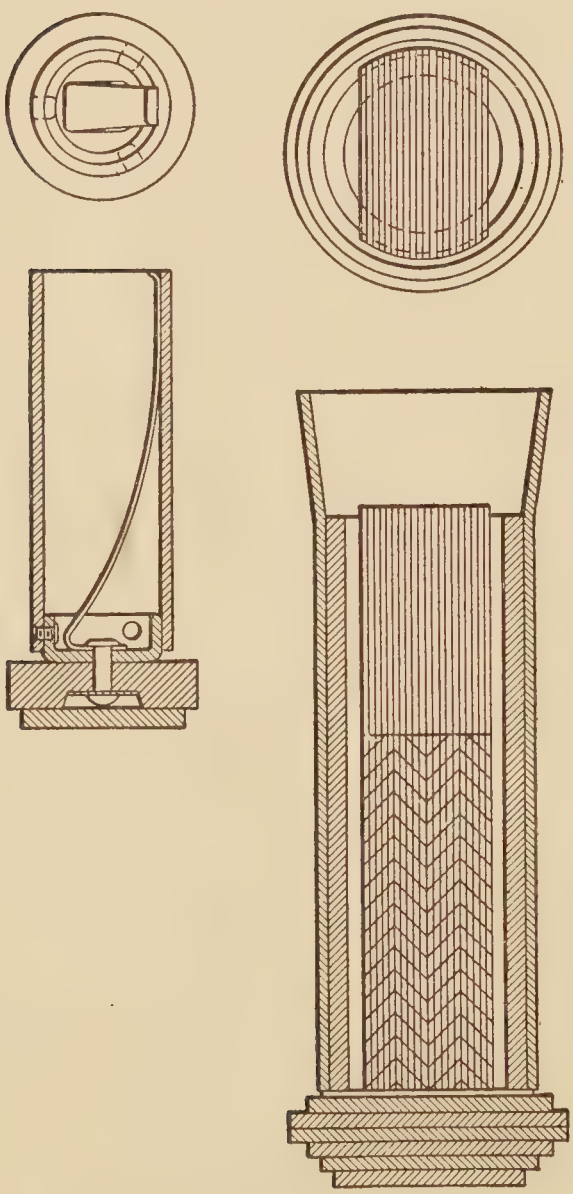

FIG. 25

This terminal is equipped with stirrup doors, a speed breaker on the receiving line, a signal light, and motor-starting contacts and signal lamp. It is designed for use at intermediate points only, as indicated at *l*, Fig. 18.

53. Switching Device.—The switching device is a flat cylindrical casting containing a rotor that is actuated by a handle. When the handle is thrown 180° or half-way around in either direction, it switches the carriers from one line to another. The switching device is installed at intermediate relay offices to afford through operation to the distant office when the intermediate office is closed.

54. Tube Carriers.—The pneumatic tube carrier used to hold the messages consists of a light hollow cylinder, the head of which is closed by a circular felt pad fitting the tube suffi-

ciently tight to prevent air from passing and at the same time offering as little friction as possible. The cylinder or body of the tube is slightly smaller in diameter than the felt head and is made of various materials according to the type of carrier, such as leather, fiber, metal, and gutta percha.

In Fig. 25 are shown two types of British Post Office carriers. The fiber carrier, which has a flat spring to hold the messages, is generally used for house tubes. The gutta-percha carrier is used for street service. This carrier has a felt head

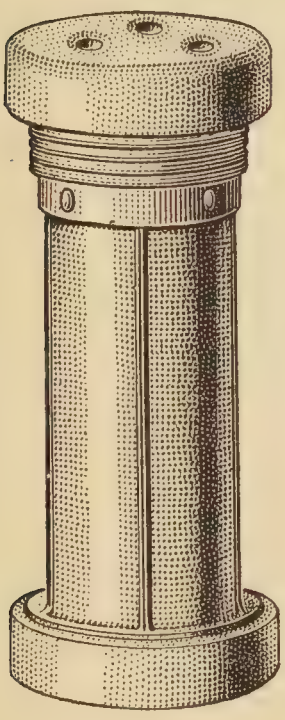

FIG. 26

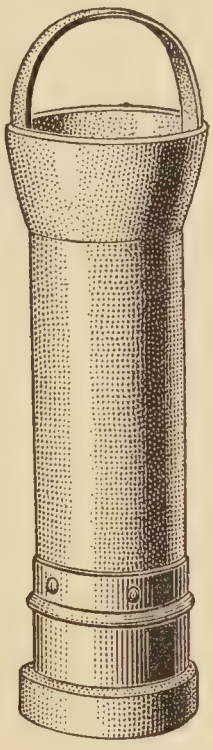

FIG. 27

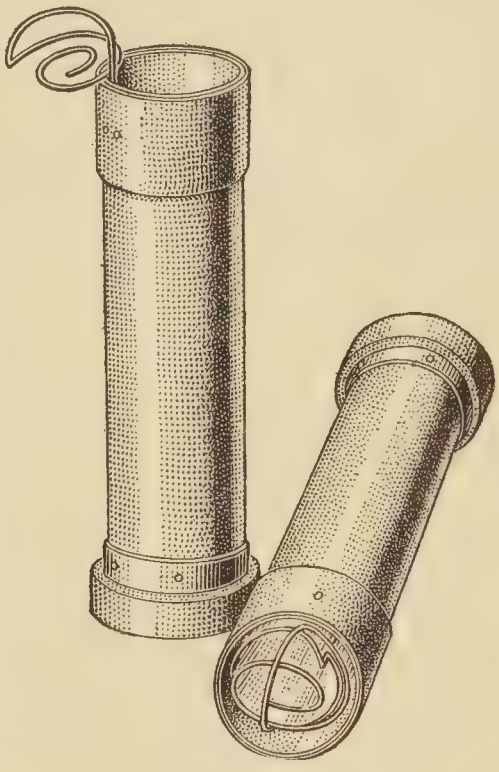

FIG. 28

that extends beyond the gutta-percha tube and at the open end is made in the form of a skirt. This skirt has a tendency to swell when the carrier is in motion, owing to the current of air in the tube, which in a measure helps to prevent the air from getting past the felt head of the carrier.

55. In Fig. 26 is seen a double-end carrier of American manufacture which has a felt head on each end. To load or unload this carrier it is necessary to unscrew the open end. An open-end carrier with a strap secured across the end opening is shown in Fig. 27. The strap is of advantage in spreading against the walls of the tube while the carrier is in motion, which assists in maintaining consistent speed without blocking as long as the carrier is being constantly impelled in one direc-

tion. Another open-end carrier is shown in Fig. 28. This carrier has a wire guard that is easily removable to enable the contents to be extracted. The guard is readily sprung over the end of the carrier after loading, thus effectively securing its contents. As with other types, this carrier has a felt head.

The velocity of the carriers traveling through the tubes varies between 900 and 2,600 feet per minute, depending on the length of the tube. A carrier will travel through a long tube much slower than a short tube, owing to the fact that the velocity at constant air pressure decreases with the length of the tube. Tubes for use between telegraph offices seldom exceed 7,000 feet in length

CORD CONVEYER SYSTEM

56. Principle of Operation.—A selective conveyer, known as the cord conveyer system, is used with considerable success by the Western Union Telegraph Company. This system consists of a framework similar to that of a belt conveyer having grooved wooden driving rollers mounted at the ends of the framework structure. In Western Union practice, one contin-

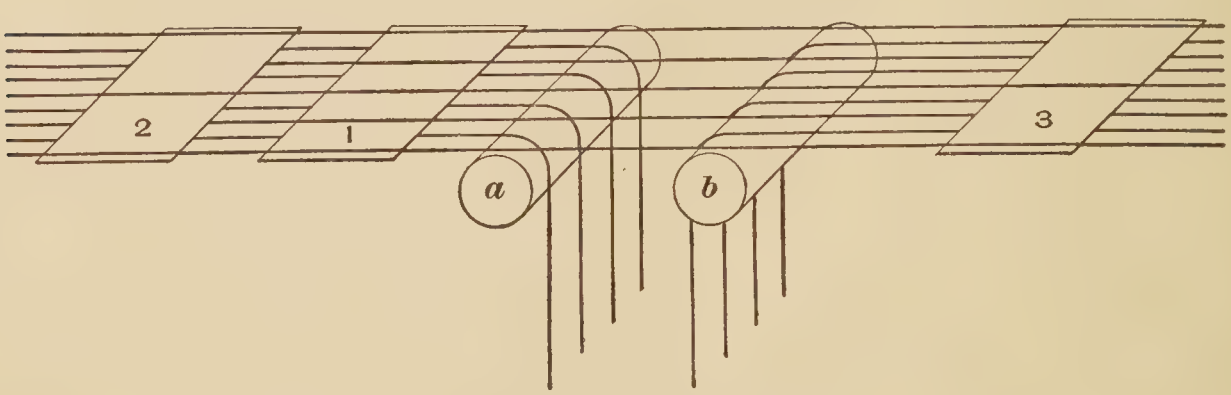

FIG. 29

uous length of cord is wound around these grooved rollers fourteen times. In the space between the end driving rollers are idler rollers, which serve to hold the cords in their proper spaced positions in the grooves provided for that purpose on the rollers. By suitable arrangements at designated stations, the conveyer will pick up and deliver messages selectively. This is accomplished without the use of carriers.

57. The manner in which this system operates may be more readily visualized by referring to Fig. 29. The horizontal lines represent cords all moving from left to right. Some of

the cords turn downwards at roller *a*, pass under other rollers that are not shown, to the roller *b*, and on to the right. Three message blanks numbered *1*, *2*, and *3* are inserted between the cords, so that a number of cords are under the message blank and several over it. It will be seen that blank *1* is inserted in one way, while blanks *2* and *3* are in another way. The blanks are firmly held between the cords and move along with the cords.

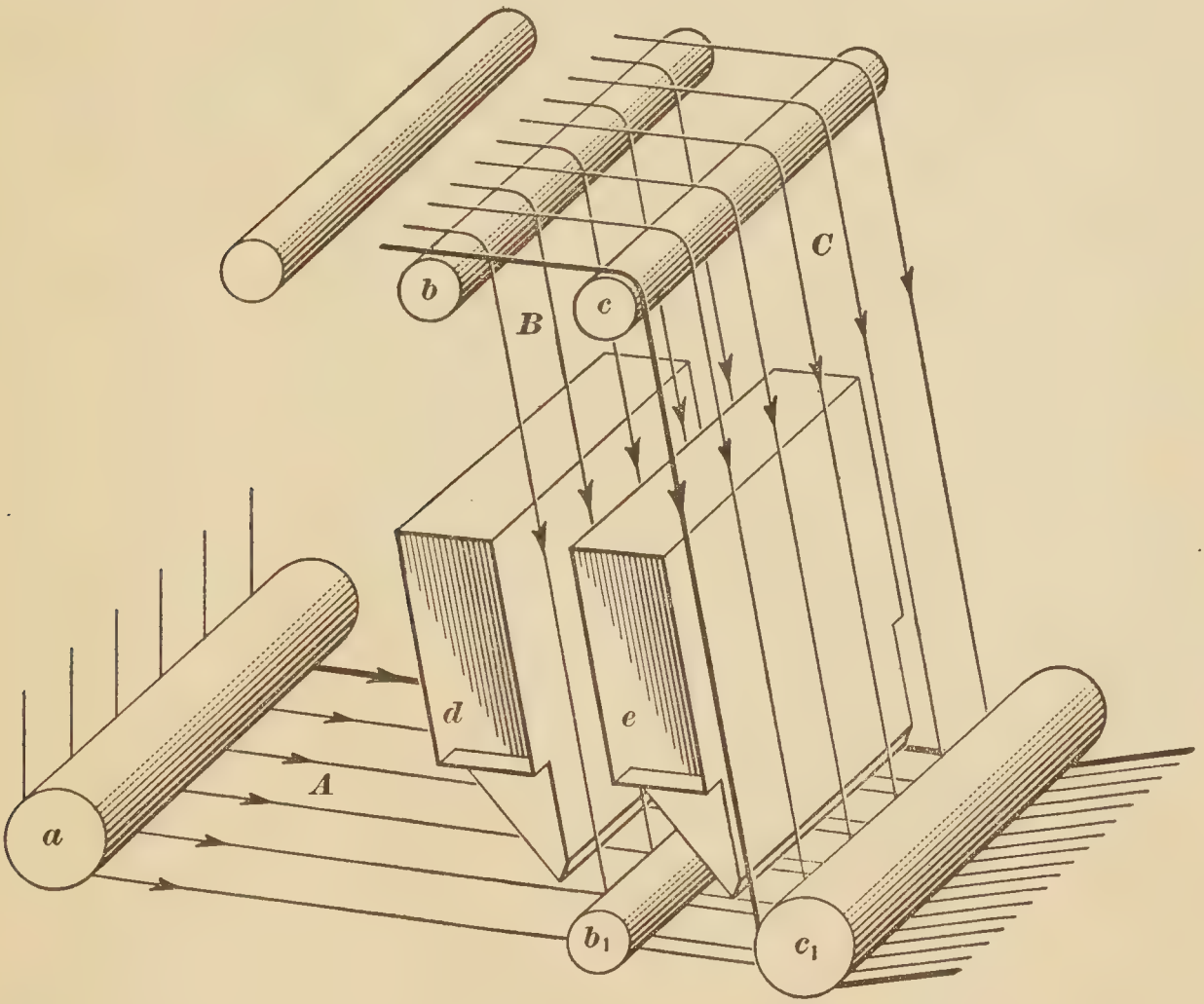

FIG. 30

When blank *1* reaches roller *a*, the cords on which the blank rests take a sudden turn downwards. There is nothing left to hold the blank, hence it falls into a receptacle provided for that purpose.

Message blank *2*, on reaching roller *a*, does not fall because there remain several strands under it and these hold it until it passes between the rollers *a* and *b*, when the rest of the cords are again brought into play under the blank. Messages *2* and *3* will drop only when there is a roller that diverts the cords on which these messages rest. The details of the manner in which

the message blanks are inserted between the strands will be shown in subsequent figures.

58. Sending Station of Cord Conveyer.—The essential details of a cord-conveyer sending station are shown in Fig. 30.

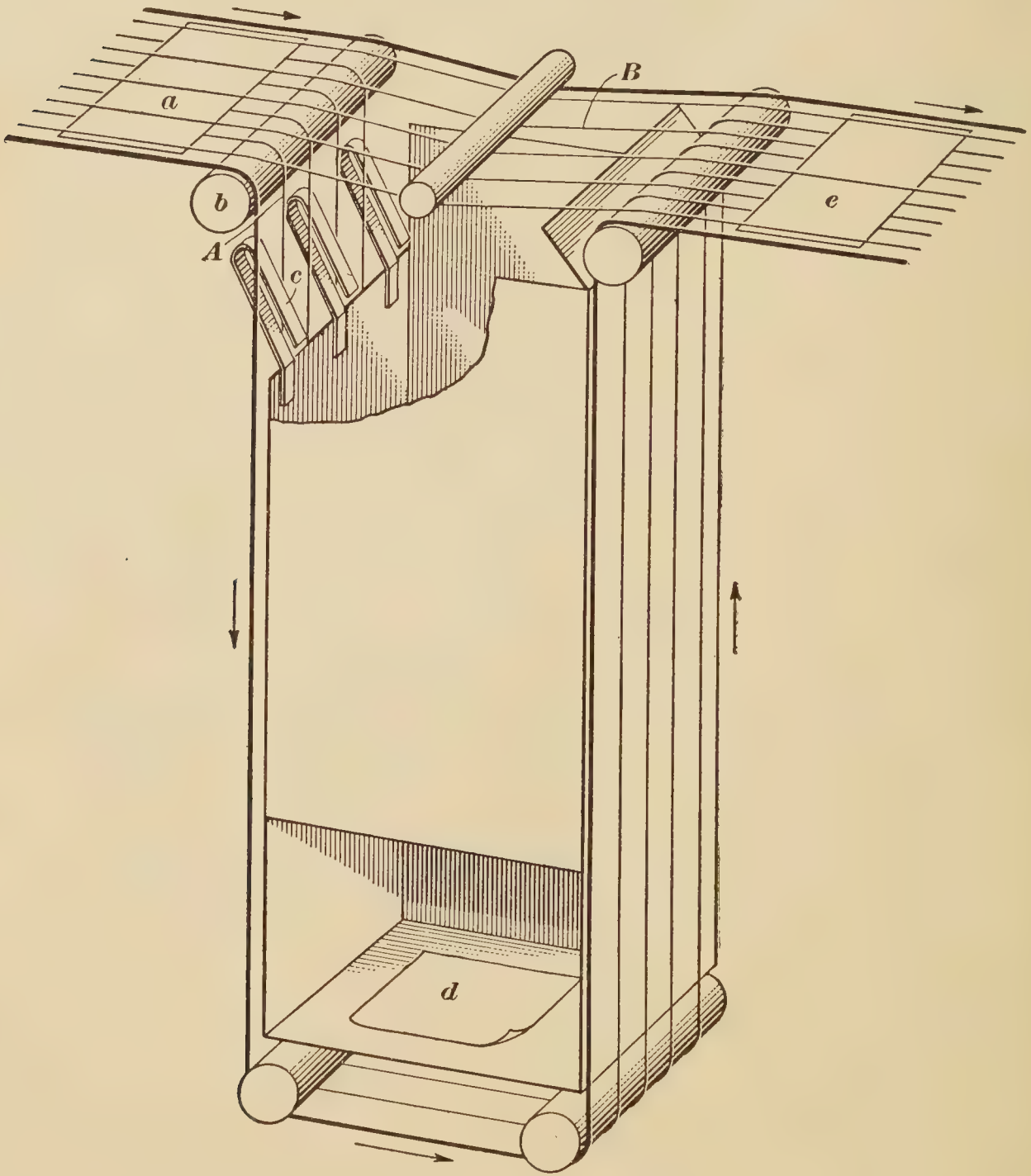

FIG. 31

Three groups of cords are here shown. The first group passes under the roller *a*, which might be designated as group *A*; the second group passes over roller *b* down to roller b_1, and this group may be designated group *B*. The third group goes over roller *c*, and down under roller c_1, and this group will be called

group *C*. The roller c_1 serves also as a combiner for all the cords of groups *A*, *B*, and *C*.

Two message chutes *d* and *e* are shown. Messages placed in chute *d* fall between the groups *A* and *B* of cord conveyers, and messages placed in chute *e* have the groups *A* and *B* as bottom support and the group *C* over them. All the message blanks pass under the roller c_1, and go on to their respective stations.

59. Cord-Conveyer Receiving Station.—At the first receiving station, as shown in Fig. 31, the arriving message blank *a* goes as far as the roller *b*, where the group *A* of cords turn down, and the message blank *a* with no support at the bottom falls down over the metal deflectors *c* to the bottom of the receptacle as indicated at *d*. The message blank *e* passed over the first station because the group *B* of wires, Fig. 30, acted as support, and this message blank *e* continues until it comes to its own receiving station, where it will also fall into a receiving container.

No special attention has here been paid to the arrangement and winding of the conveyer cord. This cord is wrapped around the rollers in grooves numbered from 1 to 14. The cord is driven by the rollers, which in turn are driven by a motor through the medium of a heavy driving cord at both ends of the rollers. The driving cord is extended to all the rollers. The carrier cord starts on its journey at the groove designated as 1, then travels to the distant terminal, returning through groove designated 2, and so on until groove 14 is reached, when it crosses over through the medium of two pulleys back to groove 1.

TELEGRAPH OFFICE COMBINING ALL DEPARTMENTS ON ONE FLOOR

60. In Fig. 32 is shown the layout of an office of a somewhat smaller type combining all departments on one floor. At the front of the office is the public lobby behind which is the counter *a* at which place local messages are filed. Near the counter is the commercial manager's desk *b*. Within convenient reach is the delivery desk *c* from which local telegrams are

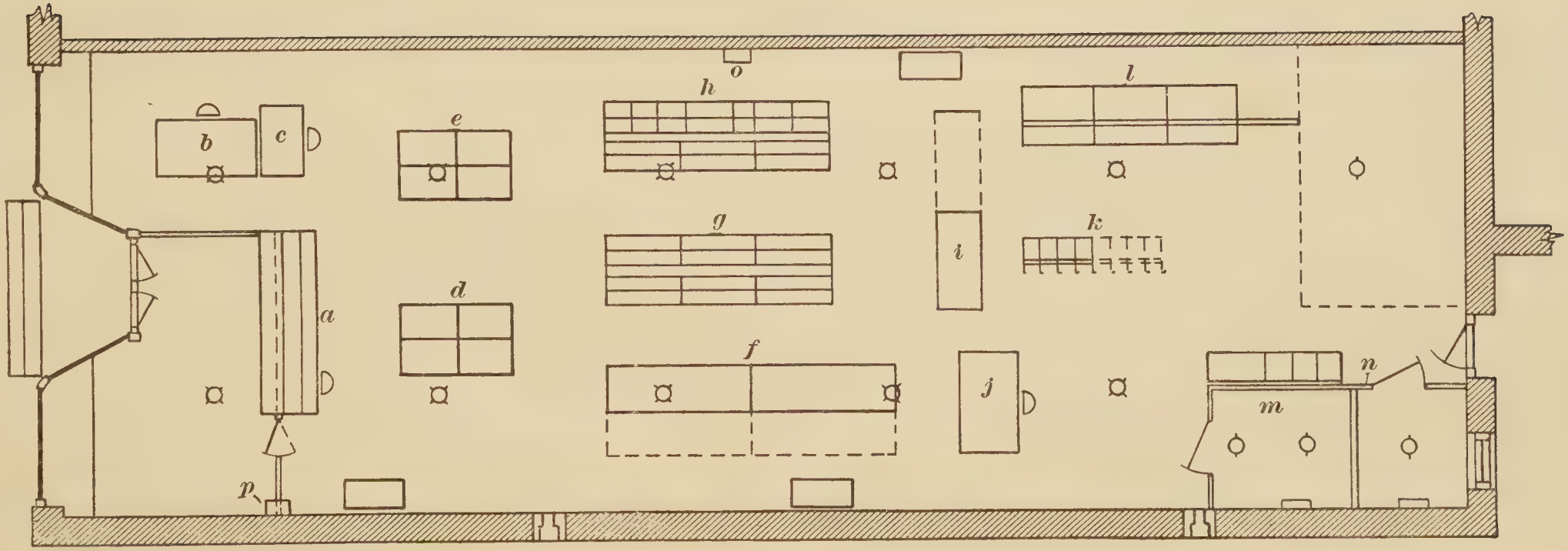

FIG. 32

booked, copied, enveloped, and finally handed to messengers for delivery. Behind the counter *a* is a four-position, or quartette, table *d*. At this table there are four single Morse circuits, one at each position. Across from this table is another quartette table *e* on which two positions are wired for duplex Morse operation with sending and receiving sides. To the rear of these tables are three repeater tables *f*, *g*, and *h* on which are placed repeater apparatus of various types. To the rear of the repeater tables is the switchboard *i* and chief operator's desk *j*. At the rear of the switchboard *i* is located the distributing frame *k*. To the right of the switchboard *i* the motor-generator plant *l* is located. The plant provides 110-, 160-, and 240-volt potentials for local and main-line current. The lighting arrangement is indicated by the conventional markings. The lavatories are located in the rear of the room as shown at *m* and *n*. Clocks are located at *o* and *p*.

TELEPHONE DEPARTMENT OF LARGE TELEGRAPH OFFICE

61. In a large telegraph office the telephone department is sometimes on a separate floor from the main telegraph operating room so as to avoid the noise of the telegraph apparatus. The telephone storage battery, the distributing frame, and the telephone positions for different kinds of service are arranged for convenient operation. Conveyers are installed for transmitting messages to different parts of the telephone department or between departments of the general office. School positions are provided where student operators may transmit and record messages by telephone for practice. An endeavor is made to make this room as sound-proof as possible by lining the ceiling with painted canvas.